ASSESSMENT OF PROXIMAL FEMUR ANTHROPOMETRY IN SOUTH INDIAN POPULATION THROUGH CADAVERIC BONES AND RADIOLOGICALLY. CORRELATING DIFFERENCE IF ANY BETWEEN OTHER ETHNIC GROUPS,ASSESSMENT OF BEST FIT IMPLANT FOR INDIAN POPULATION

Dissertation Submitted

by

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Under the guidance of

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COIMBATORE

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled **"ASSESSMENT OF PROXIMAL FEMUR ANTHROPOMETRY IN SOUTH INDIAN POPULATION THROUGH CADAVERIC BONES AND RADIOLOGICALLY. CORRELATING DIFFERENCE IF ANY BETWEEN OTHER ETHNIC GROUPS AND ASSESSMENT OF BEST FIT IMPLANT FOR INDIAN POPULATION"** is a bonafide and genuine research work carried by me under the guidance of **Dr. B.K.DINAKAR RAI(D-ORTHO.,M.S.Ortho),** Professor, Department of Orthopaedics, PSGIMS & R, Coimbatore.

Place:

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CERTIFICATE BY THE GUIDE

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ABSTRACT

Introduction:-

The morphology of the proximal femur is a topic of extensive research. The anatomy and anthropometry of proximal femur is subject to wide range of ethnic variations. The femurs of Asians & Indians are considered to be anthropometrically the smaller group. The conventional prosthesis in circulation are designed to the trends of European femora. Thus leading to various problems involved with implantation like intra op splintering of the proximal femur.

The present study addresses these issues involving ethnic differences in the geometry of the proximal femur in Indians and other ethnicity. It also evaluates the adequacy of fit of the conventional femoral stems in Indian population.

Aims and objectives:-

- To determine the proximal femur morphology in South Indian population determined with radiographs and from cadaveric dry bones
- To determine the differences between anthropometry of South Indian population and other ethnic groups.
- To determine the differences if any between the anthropometric parameters of male and female femurs.
- To estimate the dimensions of conventional cemented femoral stems (modular & monoblock bipolar) and imported modular for assessing the fit and fill in Indian femora.

Methods:-

Standardized pelvis with hip radiographs of 200 normal volunteers of indian origin were taken and the anthropometric parameters of proximal femur were templated. The parameters were compared with other Asian and European populations

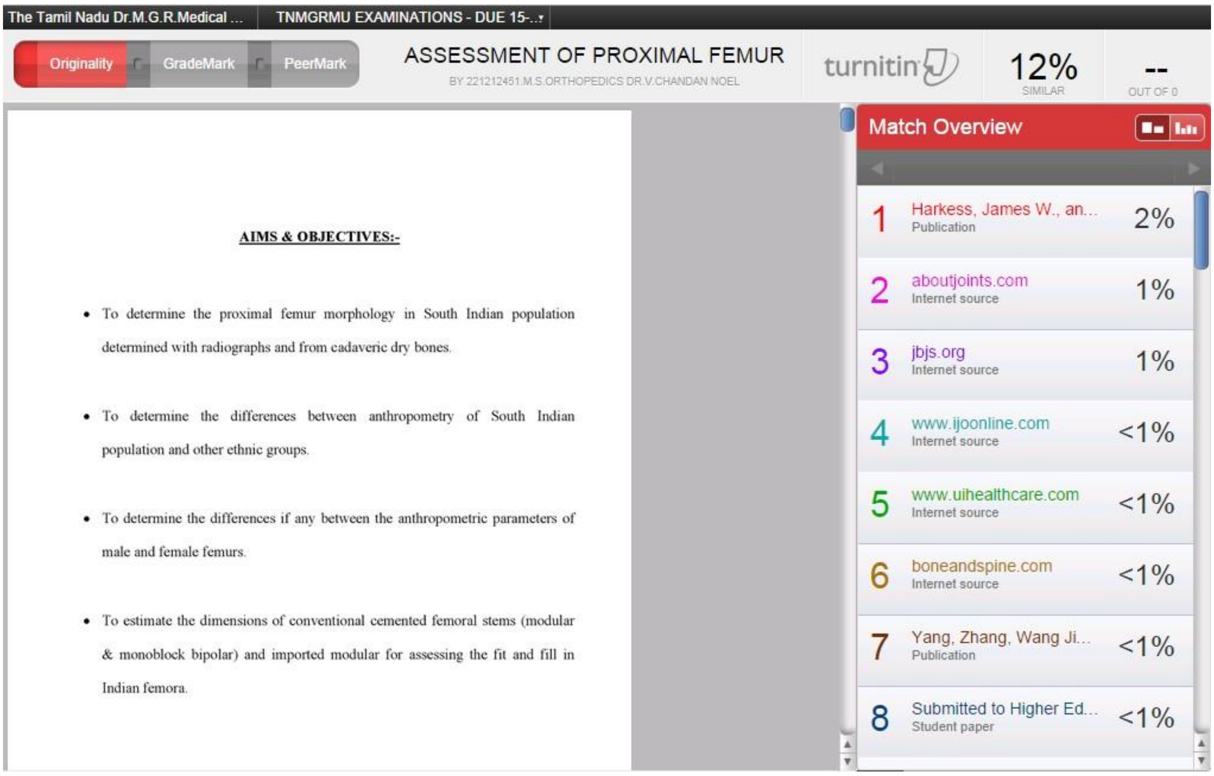
to estimate dfferences. The same parameters were templated in 50 dry bones and the fit of conventional proximal femoral prosthesis was assessed.

Conclusions:

- In our study the comparison of average measurements in male and female femora. The male femora had larger dimensions in all the anthropometric parameters.
- The canal flare index in South-Indians was an average of 3.23 with 70% of the study population having normal CFI (3-4.5), 30% of the population having a stove pipe configuration CFI (<3). Majority of the Indian population favour a un-cemented fixation (70%).
- The Asian and Indian femur bone is of much smaller sizes in comparison to European femurs in terms of endosteal diameter and offset. The mean offset difference of 4.25mm and canal was larger in the European population
- At the neck osteotomy (level-D) the mean canal-implant difference was 2-3mm for all mono-block bipolar implants indicating a very tight fit.
- The implant was found to be oversized in 17% (SMPL) and 34% (ORMED) of the femurs. Thus accounting for the regular occurrence of proximal splintering with the use of the implant.
- In summary all current implants have to be revised on population basis to fit the changing anthropometry of our proximal femur.

TABLE OF CONTENTS

PLAGIARISM CERTIFCATE



INTRODUCTION

The morphology of the proximal femur is a topic of extensive research. The hip joint is one of the most commonly replaced joint. The era of replacement has given rise to various implants that can be used to replace the proximal femur. The integral part of any replacement is to reproduce the biomechanics of the original joint in the prosthetic components in order to achieve good clinical outcome both in terms of patient and implant. Many of the conventional implant systems manufactured by various conglomerate companies are made in correlation with the sizes of the femora of Europeans. The use of these implants in the Indian population, owing to its small size of the femur has been plagued with numerous complications like intra-op splintering of the proximal end of femur. It is also the bane of the Asian-Indian Orthopedic surgeons to work with such ill-fitting implants.

Most implant systems are usually designed on the basis of European femora, which are believed to be larger than Asian population. The implantation of these prosthesis often results in problems like fractures of the proximal femur or less confirming prosthesis leading to looseing.

This present study addresses these issues involving ethnic differences in the geometry of the proximal femur in Indians and its differences between people of various ethnicity. It also evaluates the adequacy of fit of the conventional femoral stems in Indian population.

AIMS&OBJECTIVES

- To determine the proximal femur morphology in South Indian population determined with radiographs and from cadaveric dry bones.

- To determine the differences between anthropometry of South Indian population and other ethnic groups.

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- To estimate the dimensions of conventional cemented femoral stems (modular & monoblock bipolar)and imported modular for assessing the fit and fill in Indian femora.

REVIEW OF LITERATURE

INTRODUCTION :-

Over the past three centuries treatment of arthritis of various joints is one of themost researched topics in orthopaedics. Arthritis and its debilitating outcome, pain and functional impairments are well known. The hip joint being a complex & major weight bearing joint and arthritis of the same causes severe impairments. Hence the hunt was on for procedures that could restore the function and relieve the pain. Total hip arthroplasty has evolved to become the gold standard in treatment of hip arthritis, over the past three centuries in an exponential fashion and is still being extensively a subject of research.

HISTORY AND EVOLUTION OF ARTHROPLASTY:-

Era of excision arthroplasty:-

Hip and orthopaedic surgery in the 1800's was largely confined to excision ofjoints and amputations. The reason for this lack of a limb saving attitude wasbecause of a war stricken situation. Most of the wounds and injuriessuccumbing to infection as it took days to reach a proper medical centre.Liverpool and its port are known for its inflow of wounded people mostly soldiers with battle wounds at the end of wars. A radical treatment wasfollowed in the form of amputation by Dr.Henry park. It was Dr.Anthony white who hadfirst practised excision of joints at west minister hospital –London (1821),howeverthe technical ease ofamputation ledto a more wider acceptance to the procedure. The freedom of mobility to the joint was restored at the cost of stability. Dr.white had not made any publications although he was greatly recognized for his work among the medical community.

Dr. John Rhea Barton(1826) has been credited for his pioneering work in the field. He had created an intertrochanteric osteotomy in an ankylosed hip without anesthesia in less than seven minutes & manipulated the hip once again at 20 days. His reports were published in the North American medical and surgical journal. The results of his innovation were the patient was mobile at 6 weeks with a fairly painless hip which was mobile for 6 yrs.

ERA OF INTERPOSITION ARTHROPLASTY:-

By 1860 joint surgery had taken one step further ahead with a new technique of interposition arthroplasty. Dr.Auguste Stanislas from Paris, was the first to do a soft tissue interposition arthroplasty.

He was soon followed by others, it was from the pioneering work ofDr.Leopold olliers at hotel-dieu hospital in Lyon France, he developed the method of adipose tissue interposition arthroplasty.However he met with high failure rates as he had failed to anchor the interpositioned material to the adjacent bone.

After that a wide variety of inter position able materials were researched, mostof the credit goes to Dr.Vitezlav chlumsky, A Czech surgeon working atBreslau Germany, where he had tried various materials like (muscle , celluloid, silver plates , rubber struts, magnesium, zinc,glass, decalcified bone and wax).

By 1891 Dr. Themistocles gluck had developed a much newer innovation in theform of ivory ball and socket joint fixed to bone through nickel plates and screws.

By the turn of the century Dr. Benjamin murphy had described a method of excising all osteophytes around hip joint termed "cheilotomy". By early 1900's interpositional arthroplasty had gained wide popularity.

Erich and Murphy had developed a technique of interposition of a fascia lata graft. The technique is an extended thought given by a dentist Dr.Heinrich Helferich who had tried a similar procedure of fascial interposition for temporo mandibular joint arthritis.

By 1918 Dr.William Steven Baer of the john Hopkins institute, had researched about the durability of pig bladder to withhold high stresses. He had popularised a method of interpositioning pig bladder.

Sir Robert jones had brought forth a technique of interpositioning gold foil. He claims to have followed up the patient with fairly good range of movements at the hip joint with goild foil interposition up to 21 yrs of follow up.

In 1923 the Norwegian born, American bred surgeon Dr.Marius Smith Peterson placed at Boston-massachusetts invented a synthetic interpositional arthroplasty. He had used synthetic materials, after the observation he had made while recovering a piece of glass from a person. He had noted a thin membrane over the glass piece. Soon he extended this knowledge in to making mold prosthesis out of glass, but due to the complication like breakage of glass implants. This procedure was abandoned by Smith Peterson.

Over a period of time following suggestions from his dentist, he used the idea of implanting vitallium prosthesis. Soon he enjoyed the success of vitallium prosthesis and had implanted 500 vitallium prostheses. During the sourse of ten years the patients were followed up and found to have excellent results.

ERA OF PROSTHETIC HIP REPLACEMENT:-

Several descriptions of early attempts at replacement of the hip joint wereattempted from the early 1900's by various orthopaedics pioneers.They trialled various materials in to replacing the ball and socket of the hip joints.One of the earliest to was Piere Delbet of seine et marne France. He used arubber femoral prosthesis for hip replacement in 1919. He was followed by Heygroves who had tried implanting a ivory prosthesis.

But all these innovations were not received well, and met with failures. By 1948the judet brothers- john and jean judethad come up with an acrylic mouldproximal femoral prosthesis. It was received with much promise, initial resultswere very promising. But soon it fell in the line of failures as it met withcatastrophic wear rates and finally failed.

In the 1940's a radical surgical procedure was innovated by Gathrone Robertgirdlestone, as tuberculosis was very rampant. His procedure consisted ofradical resection of the proximal segment of femur. The procedurenamed afterhim is still a last resort option for failed THA's – "girdlestone excisionarthroplasty".

In the 1950's Fredreick Thompson had innovated a vitallium proximal femoral prosthesis based with collar and polished intramedullary stem. This prosthesis was further revised by Austin moore who implanted a metal implant of the same variety in Hopkins hospital 1940's for a man with large GCT of the proximal femur.

Philip wiles of Middlesex university had described methods of the first THA, using a metal implants, fixed to bone with screws. Haboush and Mc Kee in London used another metal prosthesis which used the dental acrylic cement for fixation. They had invented a metal cup with flanged claws, fixed to acetabulam with screws. But the prosthesis met with high failures due to loosening.

SIR JOHN CHARNLEY:-

Sir John Charnley, also known as the father of modern orthopaedics for his pioneering work in various aspects of orthopaedic surgery, most notable contributions to arthroplasty. He was born in the town of bury in lanccashire United Kingdom 1911. Sir John charnley is an astute clinician, an eminent orthopaedic surgeon as well as a biomedical genius.

Sir Charnley has done exhaustive pioneering work in the field of arthroplasty. One of his many innovations was the founding of “low friction arthroplasty”. He had mainly started his research with studying the lubrication nd frictional forces occurring at various joints in various animals.[1, 2, 3,4]He immensely researched the biomechanics of the human hip joint, he had observed one of his patients who had a squeaking sound in his replaced hip joint, and through research he uncovered facts regarding increased frictional resistance around the articulating surfaces of the implant. [2,3]

In addition to reducing the frictional forces acting over the hip he had also proposed a frictional torque produced secondary to turning moment produced by the metal femoral head in the socket. He had there on introduced a smaller size head which is the 22 mm head of the charnley’s original prosthesis.

Many of these principals stand true to this day, have paved way to current concepts in the arthroplasty of the hip.[1,2,3]Kiaer and jansen of copenhagen had reported attaching plastic cups to femoral head with the use of acrylic cement which they had borrowed from the dental surgeons. There were further publications of Haboush et al using acrylic cement for the fixation of the femoral prosthesis. However it was charnley who was able to connect the dots.

In his journal “Anchorage of the femoral head prosthesis to the shaft of the femur”[5], Sir Charnley had suggested the bone cement acted as a “GROUT” and not as a GLUE, the fixation was not achieved by adhesion but by an interlock between the cement and the prosthetic stem. He also touched regarding the pressurization of the cement so that it fills all the interstices in the bone, it is paramount in transmission of weight over a larger surface area in the bone.

Sir Charnley had been using the poly tetrafluroethylene which was believed to be a self lubricating synthetic as a bearing surface. This material was much similar to the UHMWP (ultrahigh molecular weight polyethylene) except for fluorine substitution instead of the carbon. After implantation in about 300 patients in the first few years, Sir Charnley had seen lot of complications mainly extensive wear rates and loosening of the implants.[3,5] Also with extensive wear rates, they also showed an intense forgein body reaction to the fine debris.

The search for the next durable material available for implantation was exhaustive. It was the innovation of Hoechst (Oberhausen, Germany) who first introduced UHMWP (ultra high molecular weight polyethylene) it was initially used mainly in textile looms. This material was tested durable in their in vivo studies by Charnleys assistants following which, the first hip with a UHMWP socket was implanted in the November of 1962.[5]

Another integral part of charnleys concepts in total hip arthroplasty was to osteotomize the greater trochanter and move it distally and laterally. This could give the theoretically said advantage of lengthening the lever arm of the abductor mechanism. Further he had also deepened the acetabular cavity so as to shorten the lever arm of the body weight. Theoretically in conditions were in the head of the femur is lost or the neck of the femur is shortened such as arthritis and other disorders or external rotation deformities such as that in DDH. The ratio of the lever arm of the body weight to that of the abductors was said to be 4:1. By following charnleys surgical principles it was possible to alter this lever arm close to a ratio of 1:1.All these principles were integral to charnleys concept of low frictional torque arthroplasty[1,2,3,5],Although there were lot of problems concerning the union of the trochanter and persistent pain and extensive laborious surgery. Although most of the arthroplasties are done without an osteotomy, but his principles and understanding of the biomechanics of the hip joint stand true to this day.

EVOLUTION OF BIPOLAR HEMIARTHROPLASTY:-

Bipolar hemiarthoplasty was introduced by James.E.Bateman and Gilberty. Previously in the 1950-60 Dr. Austin moore had tried a similar prosthesis in a patient with recurrent giant cell tumor of the proximal femur with good results. He had further observed bony in growth over the implant hence he extended the same principle in to making the Austin moore prosthesis which was fixed with bone ingrowth. After that by 1974 James E Bateman along with Gilberty introduced the bipolar implant as an intermediate to THR and the Austin moore replacement. The bipolar implant consisted of 2 surfaces, the acetabulum – outer shell, inner head-shell. So movement occurred in two articulations hence termed bipolar implant.[46,47] Various versions of the implant have been introduced commonly used are the Monk duo pleet (Monk 1976), Talwalker bipolar endoprosthesis (Inor, India), Hastings bipolar endoprosthesis and modular bipolar endoprosthesis (Bio-technic,France).

ANATOMY OF THE ACETABULUM AND THE PROXIMAL FEMUR:-

The topography of the innominate bone is integral in any study of the hip. The innominate bone has three parts in its making the ilium, ischium and the pubic bones. It is shaped irregular, constricted centrally and expansive as we go above and below. It also has the deep cup shaped acetabulum which articulates with the femoral head laterally to make the hip joint. Antero-inferiorly we have the triangular obturator foramen. The principle site of confluence of all the three bones of the pelvic girdle is the acetabulum

ACETABULUM:-

The acetabulum is a deep hemispherical cavity on the lateral aspect of the innominate bone forming the confluence of the ilium ischium and pubis in the innominate bone. It has an articular surface also called the lunate surface, the weight bearing dome of the lunate surface which is widest above transmits the body weight on to the femur. This articular surface is contributed $2/5^{th}$ by the ilium and ischium , $1/5^{th}$ by pubic bone. There is a rough non articular region in the floor of the acetabulum centrally called the acetabular fossa, from the depths of which arise the ligamentum teres to the head of the femur. The irregular margin of the acetabulum is deficient inferiorly called the acetabular notch.

There is a lot of controversy regarding the orientation of the acetabulum literature wise. The universally accepted is the anteverted acetabulum with an average anteversion of 40 degrees as described in various studies.[6,7,8]These authors have made their measurements of the pelvis with the brim horizontally where it can be appreciated that the acetabulum is facing forwards.

However considerable controversy has risen, after the findings published by Mc kibbin et al. in the erect posture the anterior superios iliac spines and pubic symphysis are all in the same position and the acetabulum is not in an obvious anteversion and found to be facing 45 degrees laterally and 15 degrees forward, whereas the same is much accentuated in sitting posture of the pelvis. This has been attributed to the attitude of the lumbar spine with flexion of the pelvis on the lumbar spine accentuating the and lumbar lordosis causing the opposite.

THE PROXIMAL FEMUR:-

The femur is the longest and strongest bone in the human body. Its length is associated with a striding gait and its strength with its weight and muscular forces. The femur consists of a spherical articular head projecting medially over a short neck from the shaft of the femur. It is one of the major weightbearing bone involved in transmission of weight from the axial skeleton & pelvis on to the tibia. Its length is approximately a quarter of theperson's height.

The proximal femur consists of head, neck, trochanters (greater & lesser trochanter) and the shaft (proximal). The head of the femur is round to spherical in shape. Two thirds of the sphere is covered by the articular cartilage with a medially placed central depression/pit in the head called the fovea. The ligament to the head of femur (ligamentum teres) inserts in to the fovea. The head is attached to a trapezoidal neck with broad base which is in continuity with the shaft of the femur.

The proximal shaft forms an oblique angulation with that of the neck and head, which is greatest at birth and gradually decreases. Laterally placed over the apex of the proximal shaft is the greater trochanter which serves as an attachment site for the abductor musculature. This neck shaft angle normally is 126 degrees, causing lateralization of the abductor mechanism from the center of rotation (the femoral head).

The proximal femur also has a slight posterior bowing up to the level of the lesser trochanter, which later gets transformed to an anterior bow. There is also a gradual medial bow in the femur as we go down in to the shaft. This is one of the anthropometrically significant parameter frequently unrecognized or not given importance by implant manufacturers.

The coronal plane of the femur is referenced with its posterior condyles distally. When referenced to condyles, the head and neck of the proximal femur are rotated anteriorly in relation to the condyles. This anterior rotation of the head and neck is termed anteversion. The normal anteversion of the proximal femur is around an average of 10-15 degrees, 10 degrees being in males & 15 degrees females.[10,31]

There is a faint line in between the two trochanters, the intertrochanteric line. This line serves as a landmark for the attachment of the capsule. The shaft of the femur is tubular and narrow centrally but expansile proximally and distally. The axis of the femoral shaft makes an angulation of 5-7 degrees with that of the axis of tibia, because of the lateralization of the abductor mechanism.

THE INTERNAL ARCHITECTURE OF THE PROXIMAL FEMUR:-

The proximal end of femur is made up of a fragile yet collectively a strong lattice work of **"struts and trusses"**formed by the trabecular framework of the bones. Galileo recognized the significance of this network of trabecular bones, forming hollow cylinders. They were described as weight for weight and stronger than solid rods.

THE CALCAR FEMORALE:-

The calcar femorale is a thin vertical plate of bone. This plate extends from the linea aspera and ascends in to the trabeculation of the neck of femur & joins the posterior wall of the neck of the femur medially. As Bigelowet al described it as the true neck of femur. Laterally it continues in to the trabeculation of the neck of femur gradually dispersing in to the fine trabeculations.

The significance of this calcar is that it is a dense plate of bone, The shoulder of any hip joint prosthesis used is going to rest over the calcar femorle and helps in transmitting the stress of weight bearing in to the calcar femorale.

THE HIP JOINT:-

ARTICULAR SURFACES:-

The hip joint is a ball and socket multi-axial joint. The articulation of the hip joint is between the head of femur and the acetabulum. The femoral head is more of ovoid to spherical, the acetabulum is a cup shaped (cotyloid) structure. Though reciprocally curved they are not completely congruent structures. The femoral head is covered by articular cartilage throughout except for a small rough non articular part in the head the fovea. The fovea is a rough pit for the insertion of the ligamentum teres- the ligament of the head of femur. It holds the artery to the head of femur and serves a conduit of blood supply to the epiphysis during the developmental period.

The articular cartilage is thickest in its antero-superior part in the scetabulum and antero-lateral part of the head of the femur. The acetabular articular surface is an incomplete ring lunate shaped (crescent shaped), it is deficient below opposite the acetabular notch & at the acetabular fossa which is covered by fibro-elastic fat covered by synovial membrane. As such the acetabular depth is inadequate, this depth in increased by the presence of the LABRUM. The labrum is a triangular in cross section, the base of which attaches to the acetabular rim, the apex forms the free margin. It has been implicated to have a proprioceptive role in the hip joint, confers stability and acts as a “water seal” for the joint.

CAPSULAR STRUCTURES:-

The capsule is a strong structure attached 5-6mm beyond the labral margin, anteriorly along the intertrochanteric line & basi-cervical neck of femur. Posteriorly it is attached 1cm above the intertrochanteric area. The structure is thick anteriorly & superiorly due to maximal stress in the area. Two sequences of fibres are seen circular and longitudinal. The internal circular fibres the zona orbicularis forms a collar around he femoral neck. The external longitudinal fibres blend along with the iliofemoral ligament. The capsule is strengthened further by ischio-femoral and pubo-femoral ligaments.

THE LIGAMENTS :-

There are 5 ligaments in the hip joint.

1. The iliofemoral
2. Pubo femoral
3. Ischio femoral
4. Ligamentum teres
5. Transverse acetabular ligament

The ilio-femoral ligament is a strong and ‘Y’ shaped structure. Also called the ligament of bigelow. It is attached anteriorly along the anterior inferior iliac spine to the intertrochanteric line. It is taut in extension, ER and adduction.

The pubofemoral ligament is triangular, base attached to the ilio pubic eminence antero inferiorly and blends with the capsule and medial aspect of iliofemoral ligament. It is taut in extension, adduction and internal rotation.

The ischio-femoral ligament consists of superior ischio femoral ligament and lateral & medial inferior ischio femoral ligament. It extends from the ischium to the base of the femoral neck and it is taut in abduction.

The transverse acetabular ligament part of the labrum spans across the acetabular notch forms a foramen through which vessels enter the hip joint.

The ligament teres or the ligament to the head of the femur arises with its apex to the fovea, wide based attachment to the acetabular notch. It is covered in synovial membrane, ligament appears to be taut in semi-flexed and adducted positions.

SYNOVIAL MEMBRANE:-

As a synovial ball and socket joint joint,The hip synovial attachment starts and covers the femoral articular surface, intra capsular neck and passes to inner surface of the capsule to cover the labrum. It also invests the ligamentum teres and the fat in the depths of the acetabular fossa. It connects with a bursa underlying the ilio-psoas anteriorly

BIOMECHANICS OF THE HIP JOINT:-

Biomechanics in relation to arthroplasty are completely different from that of plates, screws and nails. Any plate screw or nail is only going to give the bone a partial support until it unites, where as a replacement prosthesis is going to remain within the body. The prosthesis is going to undergo variable amount of stresses through cyclic loading over the years. A thorough understanding of the biomechanics is paramount to understanding& analysing prosthetic constraints. As in replacements (partial/total) sometimes the prosthesis may be subjected to 10-12 times the weight of the body. For optimal results and success of procedure is always achieved with smart choice in prosthesis including durability of the metal, type of fixation, sizing, bearing surfaces and surgical procedure itself. To get there we must first develop a proper understanding of the forces acting over the hip joint.

ALIGNMENT AND AXES OF THE LOWER LIMB:-

The mechanical axis of a long bone is defined as the line that passes through the joint center of the proximal and distal joints. The anatomic axis of the long bones is defined as the line that passes through center of the diaphysis along the length of the bone. The mechanical axes of the lower limb defined as the line drawn on a standing long leg radiograph from the center of the femoral head to the center of the talar dome. This mechanical axis must pass through the center of the knee, called as neutral mechanical axes. The anatomical axis and mechanical axis pass through the center of the tibial diaphysis from the knee joint below. The anatomical axis of the femur is 6 degrees of valgus in relation to the mechanical axis, owing to the lateralization of the abductor mechanism & bipedal gait.

FORCES ACTING ON THE HIP JOINT:-

Of all the earthly species the bipedal gait has evolved in birds and mankind. So when the weight of the body is being borne by both the legs , the force of the body weight is transmitted to the two hips equally. Under these circumstances the whole weight of the **body** except for the weight of the legs itself is being borne by the two hips. The resultant vector of this weight is vertical. So while we stand on our legs the compressive forces acting on each of our femoral heads will be approximately close to $1/3^{rd}$ of the body weight**.**[32]

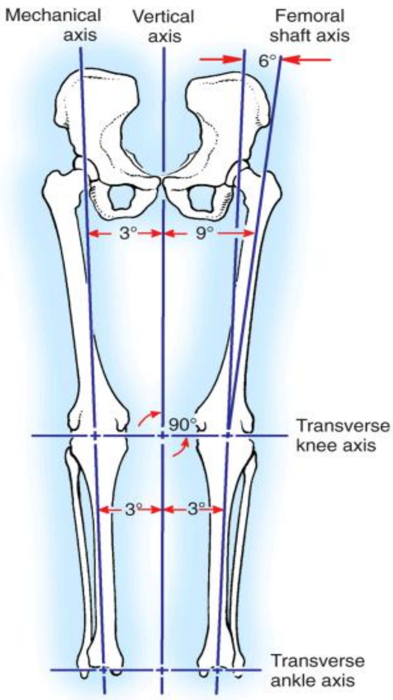


Figure 1- AXIS OF LOWER LIMB

To describe the forces exerted over the hip joint, the body weight is shown as a load applied to a lever arm extending from the body's center of gravity to that of the femoral heads. The abductor musculature act on a lever arm extending from the lateral aspect of the greater trochanter to the center of the femoral heads. During the single leg stance the center of gravity moves away from the supporting limb and is now calculated as a part of the body weight. This will exert a turning moment on the femoral head of the supporting limb. In order to support the weight of the body and prevent the unsupported hemi-pelvis from drooping,the abductor musculature must act in unison to prevent the lever arm of the body weight from doing so. The lever arm of the abductor musculature represented by (BO) is considerably shorter than that of the body weight acting through the center of gravity (OC). The ratio of the lever arm of the body weight to that of the abductor musculature is around 2.5:1. The abductor muscles must exert a force of about 2.5 times that of the body weight to steady the pelvis while in single leg stance. During the process the estimated load that acts over the femoral head during each single leg stance can be estimated close to 3-4 times that of the effective weight of the body.

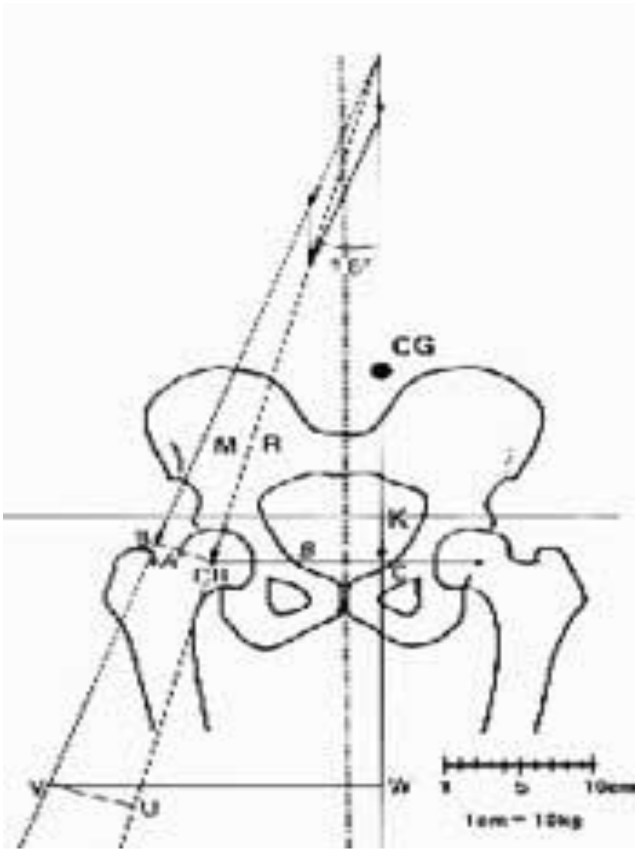


Figure 2-BIOMECHANICS OF HIP JOINT

Various authors have demonstrated through studies calculating the peak stresses acting over the hip joint during various activities of daily living. There by hypothesizing the various stresses likely to be encountered by the replaced prosthetic hip.

Crowinshield et al [36]calculated peak contact forces of up to 3-5 times that of the body weight during normal gait. **Davey et al**[37] has recorded peak joint contact forces of up to 2.6-2.8 times the body weight during single leg stance phase of gait. Some of the authors have even recorded forces of up to 10 times that of body weight during running, lifting and jogs.

Forces in the hip joint act not only in the coronal plane but also in the sagittal plane. The center of gravity of the hip joint passes anterior to the S-2 vertebra posterior to the axis of the hip joint in the midline. Therefore in a flexed hip that is loaded forces act in this direction (15-45 degrees anterior to the saggital plane) forcing the prosthesis in to retroversion. **Brand et al**[38] measured these out of plane forces to be 0.6-0.8 times body weight.

VARIOUS ANTHROPOMETRIC DIMENSIONS & THEIR INFLUENCE ON THE PROXIMAL FEMUR :

There are numerous anthropometric parameters exclusive to the femur, especially its proximal end. Accurate reproduction of these parameters is paramount for the success of any replacement procedure concerning the proximal femur, as each parameter has its influence over the biomechanics of the proximal femur.'

IMPORTANT ANTHROPOMETRIC PARAMETERS:-

- Femoral head diameter
- Neck width and length
- Femoral head offset
- Endosteal canal diameters& Canal flare index
- Version of the neck
- Neck shaft angle
- Angulation of the shaft

FEMORAL HEAD DIAMETER:-

The diameter of the femoral head and its accurate reproduction is very important for a successful arthroplasty. Especially when doing a hemiarthroplasty. An accurate sizing of the femoral head must be made so as to prevent prosthetic joint dislocations. In THR's, the ratio of the femoral head – neck diameter have a substantial effect over the range of motion. Proper selection must be done so as to restore the precise center of rotation of the joint. All these ultimately decide the stability of the implant and articulation. Over sizing of the prosthetic femoral head will result in impingement, leading to an accelerated polyethylene wear. This will later on result in component loosening and chronic thigh pain.

FEMORAL NECK WIDTH & LENGTH:-

The width of the femoral neck is another important anthropometric parameter. Accurate reproduction of this parameter was essential so as to avoid problems like impingement. The neck width & length of the femur has been assessed in various studies. The mean neck widths done in similar studies on Indian population were found to be 3.097cm by **D.RAVICHANDRAN et al** [24]**.** In another study by **SIWACH et al**[33]in Indian population had observed around 3.18cm neck width.

The mean neck length was found to be 3.18cms in a study done by **D.RAVICHANDRAN et al**[24]. In another study on Indian population by **SIWACH et al** [19]the mean neck length was found to be 3.72cms. The minimum neck length evaluated was around 2.6cms in both the studies.

The length of the femoral neck is important to restore the limb length. It is one of the major determinants of the abductor moment arm. Inadequate restoration of the femoral neck length will result in shortening of the abductor moment arm, causing a limping gait. The joint reaction forces will be increased in the face of improperly restored femoral neck length.

FEMORAL OFFSET:-

The femoral offset usually denotes the horizontal offset of the proximal femur. The horizontal offset is denoted by the distance between the center of the femoral head to the axis of the femoral shaft. Reproduction of this anthropometric parameter during replacement surgeries is of the utmost importance for a successful outcome. This offset is said to vary from 40-44mm through various studies. Of most importance is that of **MC GORY et al**who has described the correlation between length of the abductor lever arm and the horizontal offset of femur**.** An improper restoration of this parameter will result in a lurching gait and improper force generation in the abductor musculature. [13]

The femoral offset is found to be affected by various other parameters most importantly the neck shaft angle and the version of the femur. The neck shaft angle determines the size of the anatomical offset, the ante-version of the femoral neck defines “the physiological offset”. Any increase in the ante-version will result in back displacement of the greater trochanter, which in turn will cause decrease in the functional offset thereby decreasing the leverarm of the abductor musculature. This in turn will lead to inadequate power generation in the abductor muscles.[13]

ENDOSTEAL DIAMETERS:-

The endosteal dimensions of the proximal femur are a subject of immense discussion. Becsuse of the need for an exact bone-implant fit in the proximal metaphysis and distal diaphysis of the femur. Theproximal femoral endosteum is unique in its variation with race,lifestyle,age and sex. The adequacy of implant-bone fit has a direct influence on the outcome of the replacement procedure itself. Inadequate fit between the implant and bone will result in micro motion of the implant on the long run resulting in a persistent thigh pain in cementless femoral stems.[35]Several studies have pointed out that undersized or mismatched implant will produce micro motion of up to 200 micra or excess with weight bearing & loading of up to 2-4 times the body weight. It is with considerable proof that for bony ingrowth to occur the loads must be minimized to 10-14 micra or less in porous coated implants.[34]

On the other spectrum ill matching implants , that is an oversized implant will be difficult to implant with increased occurrence of intra operative fractures also well documented in case studies.[35] Numerous studies have shown geographical variation in different ethnic groupand mandates for use of implants specifically fitting the endosteal dimensions of the population.[33] However in a study by**Noble et al**[19], has concluded the extent of variability in endosteal dimensions. There was no proportional relationship between shape and size of the medullary canal. The possibility of designing an implant based on the population averages of high and low is not an achievable task.[19]

The femoral canal does not have a defined universal shape. The canal anatomy is broad and continuous spectrum. This is well defined by the canal flare index, the femoral canal can have anywhere between champagne fluted to the stove pipe like an appearance, which can be quantified using the canal flare index. Hence characterizing its shape in to a single canal shape is not possible due to the wide variance it exhibits. It also shows a wide variation between the proximal metaphysis and distal medullary cavity dimensions. This type of variation is said to be changing with age, exhibited as the cortical thinning in the diaphysis predominantly leading to a widened medullary canal from the fourth decade of life onwards. These variations have to be taken in to account as the stability of the implant depends upon the balance between the proximal and distal load transfer between implant and the bone /mantle.

The canal flare index is the ratio between the proximal endosteal diameters (20mm above the lesser trochanter) to that of the diameter at the level of the isthumus. Based on these values which were studies by **Noble P.C et al**[19]**,** femurs were categorized in to three shapes. The canal flare index was found to be distributed widely from 2.4-7.0 with an average of 3.8 (+/- 0.74). The values were grouped as stovepipe canals (Canal flare index <3mm), normal canals (canal flare index 3-4.7mm) , champagne fluted appearance (4.7-6.5mm). Thus the values point to a general trend of champagne flute shaped femurs to have smaller canals, stovepipe shaped femurs to have a wider canals. These values have also said to have a propotional variation with age, elderly age group describing lesser cortical bone stock and having a stovepipe shaped femur in the more than 60 years age group predominantly.

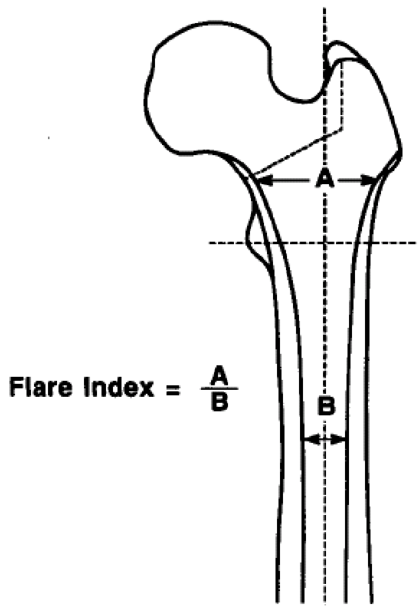


Figure 3-CANAL FLARE INDEX

VERSION OF THE NECK:-

The femur is generally referenced in the coronal plane to the posterior aspect of distal femoral condyles. There can be appreciated an anteriorly based rotation in the proximal femur, that is the neck and head of femur. This is anterior rotation is commonly referred to as anteversion of the femoral head-neck. On an average the adult femur has an anteversion of about 10-15 degrees average with the foot facing forwards. These torsional changes can be significantly high in pathological hips-DDH. The restoration of the anteversion is important in order to achieve implant stability. In cemented implants the implant is rotated anteriorly so as to accommodate the anteversion. The real problem regarding is faced in un-cemented implants (press fit) which has to be inserted along the same orientation as the neck of femur to achieve a good metaphyseal fill and roational stability while accommodating the anteversion of the femur. It is therefore important to accommodate this important parameter in implants, to circumvent this modular implants with an inbuilt anteversion have been developed. In these implants the modular stem is rotated independent of the metaphyseal portion of the cement. The few degrees of anteversion are incorporated in to regular stems also, but the main problem being requirement of separate right and left stems, thereby increasing the armamentarium of implants. Newer groups of modular prosthesis come with modular necks which are independent of the stem come in various options to adjust the length, offset and version. Any alterations in the version will produce rotational deformities, thereby altering the gait mechanics.

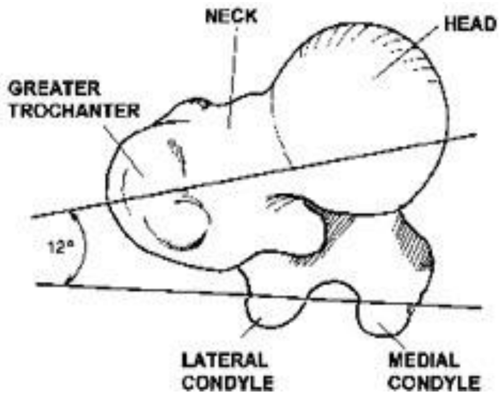


Figure 4-ANTEVERSION OF THE FEMORAL NECK

NECK SHAFT ANGLE-

The femoral neck makes an oblique angulation with that of the shaft of the femur. This causes the head of femur to overhang the femoral shaft. The angulation the neck-head of the femur makes with that of the axis of the shaft of femur is called as the Neck shaft angle or collo-diaphysel angle. The neck shaft angle functions to lateralize the abductor mechanism, the tip of greater trochanter which serves as insertion of abductors is in line with the center of rotation of the hip joint. The effect of this lateralization of the abductors results in giving a mechanical advantage so as to stabilize the pelvis whilst standing in single leg stance and to prevent its drooping. On an average the neck shaft angle is said to be 127 degrees. Any decrease in the neck shaft angle is called as coxa vara, there by increases the lever arm of the abductors and reduces the load across the hip. Whereas any increase in the neck shaft angle is called coxa valga.

THE FEMORAL STEM:-

Any total hip replacement system consists of an acetabular and femoral component. The primary function of the femoral component or the prosthetic femoral stem is to replace the resected femoral neck and head. Thereby creating a stable and pain free prosthetic articulation between the head of prosthetic femur and acetabular cup.

The key to a good replacement as far as the femoral side is concerned is to reproduce 3 key factors.

1. The vertical offset
2. The horizontal offset
3. Version of the neck

The femoral stem in itself consists of three main parts- the head, neck and the stem. It is under the control of the surgeon to choose the appropriate implant with appropriate size so as to reproduce the normal biomechanics of the hip joint in terms of leg length, offset, abductor tension and center of rotation.

The vertical height is very important so as to maintain the limb length. This can be adjusted in various ways mainly by adjusting the neck osteotomy level, usage of modular heads with an internal recess in the head on to which the morse taper on the neck of the stem fits in to. The vertical offset of the implant is primarily determined by the base length of the prosthetic neck plus the length gained by the modular heads. It can be varied by changing the depth to which the implant is inserted. In cemented implants it is possible to control the height with adequate cementing along with variation of neck osteotomy level.

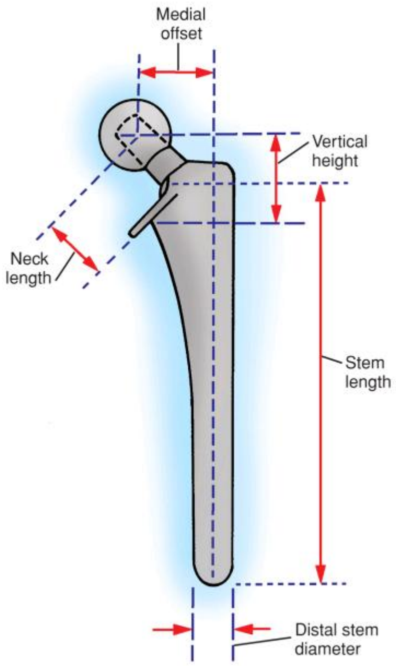


Figure 5-FEMORAL STEM

This same flexibility is not attainable whilst using a cementless fixation as depth of insertion is determined more by the fit within the femoral metaphysis, than by the neck osteotomy. Most modern stem systems have neck lengths ranging from 25-50mm, adjustments of 8-12mm are available routinely for given stem sizes.

The offset (horizontal/medial offset) is the distance between the center of the femoral head to a line through the axis of the distal part of the stem. This is primarily a function of the stem design itself. The offset determines the tension of the abductor musculature and its lever arm. An inadequate restoration of the offset will result in shortening of the abductor moment arm thereby resulting in a limp & increased joint reaction force. On occasions bony impingement can also arise secondary to inadequate restoration of the offset. Implants are available in standard offsets and high offset variations, also altering the neck stem angle to 127 degrees and attaching the neck in a more medial position.

The size of the femoral head and the neck all has a profound effect on the range of motion of the prosthetic hip joint. It is of utmost importance to select the proper sized head and neck to control the offset and avoid problems like impingement between the head-neck and acetabular rim. As chronic impingement will therefore lead to an accelerated polyethylene wear, subsequently leading to loosening and dislocation.

Barrack et al through the use of digitized implant and virtual reality testing has concluded use of higher femoral head sizes in arthroplasty (28-32mm), then those used in the past to increase the range of flexion by 8 degrees.[39] However in another study by **Burroughset al** the use of a head sizing more than 38 mm had resulted in bony impingement, dictated by the bony anatomy of the person.[40] Similar modifications were also produced in the neck region so as to avoid impingement and to achieve a greater range of motion in the implant.

Although in practical aspects the size of the head used is usually dictated by the size of the prosthetic acetabular cup in use. The ideal femoral head-neck complex consists of a trapezoidal neck with a larger diameter head without a skirt, So as to avoid problems of impingement and decreased range of motion when used along with a circular neck and non-skirted head.

Version of the neck in normal femur bone is 10-15 degrees anteverted when referenced in relation to the posterior aspect of the distal femoral condyles. In cemented femoral stems version is achieved by rotating the prosthesis anteriorly while inserting in to the cement mantle. How-ever in un-cemented prosthesis it is important to insert the prosthesis in line with the neck so as to achieve a maximal fill in the canal & rotational stability. In modular stems there is an inbuilt rotation of the stem independent of the metaphyseal portions. Some of the newer modular stems come with varying sizes of modular necks with varying sizes, offset and version so as to reproduce the accurate geometry.

TYPES OF FEMORAL STEMS:-

The femoral stems can be broadly classified in to two types

- Un-Cemented stems
- Cemented stem

There are a variety of cemented and un-cemented stems with numerous modifications to the implants. Principally they are unique and different. The type of fixation differs in both with cemented femoral stems using PMMA (bone cement) for implant fixation & un-cemented using the biological mode of “osseo-integration”.

THE UN-CEMENTED FEMORAL STEMS:-

The search for biological fixation of implants is an evolving aspect from the ages. In the 1970’s lot of problems were faced with cemented implants in terms of mechanical loosening and extensive bone loss associated with fragmented cement. So in an attempt to eliminate the cement and its complications, to look for a more biologically appealing fixation the un-cemented femoral stems came in to being.

Traditionally the use of a hybrid fixation in the form of un-cemented cup and cemented femoral stem has been supported due to excellent long term results by the national institute of health. In the United States approximately out of 200,000 are performed yearly with over 60-90 % being a un-cemented fixation.

BASIC SCIENCE BEHIND UNCEMENTED FIXATION:-

Albrektson et al[41]based on his findings in specimens retrived from humans described attachment of lamellar bone on to the implant without any intervening fibrous tissue(13). This mechanism was called osseointegration. Subsequently numerous studies both animals and human retrival studies have been done to confirm the same findings. The osseo-integration takes up to 4-12 weeks post implantation, it continues to form for over a period of 3 years. The foremost important requisite for an adequate osseo integration to occur was close and a stable contact between the bone and implant so as to minimize any micromotion that can occur (14). Micromotion of >150 micrometer can lead to fibrous tissue formation, micromotion of 40-150 micrometer leads to a combination of bone and fibrous tissue formation whereas <20 micrometer of micromotion leads to bone growth over the implant surface. The bone growth has been further said to enhance with surface modifications and other special coatings. The initial implant fixation is obtained by press fitting an oversized implant. The two main prerequisites for bone ingrowth to occur are immediate mechanical stability and intimate contact between the surfaces. The femur must be broached so as to accurately match the stem geometry. The precision factor of implant size, technique and instrumentation all must be more precisely accounted for while implanting an un-cemented femoral stem, than for a cemented femoral stem.

There are various types of un-cemented femoral stems mainly classified based on the following features.

- Shape
- Material
- Extent & location of porous surface
- Stiffness

CLASSIFICATION BASED ON SHAPE:-

Cementless stems are mainly classified in to two types based on the shape

1) Anatomical- the anatomical femoral components are built with a posterior bow in the metaphyseal portion and a variable anterior bow in the diaphyseal portion corresponding to the geometry of the femoral canal. Due to the anatomical variability these stems are side specific.

2) Straigtht-the straight stems have a symmetrical cross section and are not side specific. There by reducing the inventory. There are numerous variants in the straight stem.

Berry et al had further classified cementless femoral stems based on the stem geometries and their uniqueness in obtaining fixation.[45] Initially he classified in to four types, which has been further modified in to six types based on shape, amount of osseous contact and progression of stem fixation from proximal to distal.

Type I-IV stems are all straight stems with area of fixation increasing along with the number. Type I,II,III are tapered stems designed to obtain a more proximal fixation. The type IV is a fully coated stem bred for proximal and distal fixation.[45]

TYPE I

The type I prosthesis is also called a single wedge prosthesis. It is designed to engage the metaphyseal cortical bone in the medio-lateral plane. It primarily narrows in the medio-lateral plane proximally, then on tapers distally. The antero-posterior plane it is more of a flat & thin. The design is specific for obtaining an initial fixation through the medio-lateral wedge or a “three point fixation” through the stem of the implant. The proximal 1/3rd to the 5/8th of the implant has a circumferential coating. The three point fixation is obtained by the implant contacting with the femoral canal posteriorly in its proximal and distal extents, anteriorly in it mid extent. The broad and flat shape of the implant confers a rotational stability.

The implant only requires a proximal broaching, the distal canal does not need any reaming, making it theoretically a less invasive than its fully coated counterparts, thereby more forgiving on the endosteal blood supply. It is prudent to assess the native shape of the femoral endosteum and look for excessive narrowing down. In case it narrows down excessively the implant will engage with the canal only distally, leaving no contact or only minimal contact in the proximal porous coated surfaces as a result of which no osseointegration will occur.

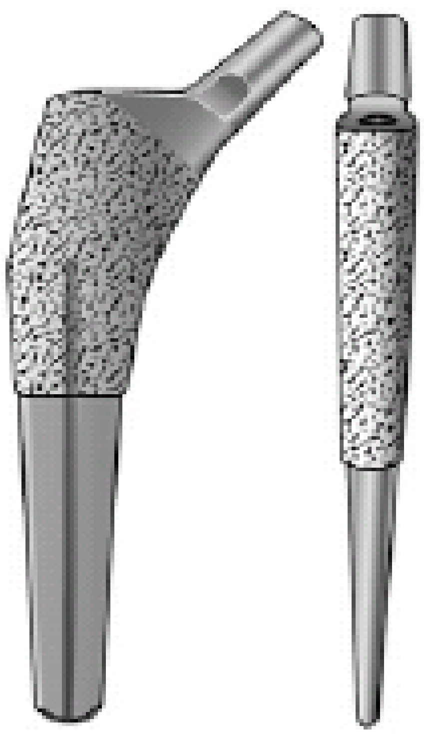


Figure 6-TYPE I (SINGLE WEDGE)

TYPE II

The type I implants were designed to create endosteal contact only in a single plane. Whereas the type II implants obtain optimal endosteal contact in two planes anterior-posterior and the medial-lateral planes. The designs are also referred to as a "DOUBLE WEDGED". The double wedge implant is designed for obtaining a metaphyseal filling. These implants present a wider antero-posterior frame in comparison to the type I implants, with either a tapered or rounded distal geometry for optimal canal filling. Often certain implants are equipped with spline and longitudinal slots called "flutes" decrease the stem stiffness & elastic modulus. The reduction in the stem stiffness theoretically reduces the stress shielding effect, thereby reducing thigh pain. For insertion of the implant the distal femoral canal has to be prepared with reaming combined with regular proximal broaching manoeuvres.

Figure 7-TYPE II (DOUBLE WEDGE-METAPHYSEAL FILLING)

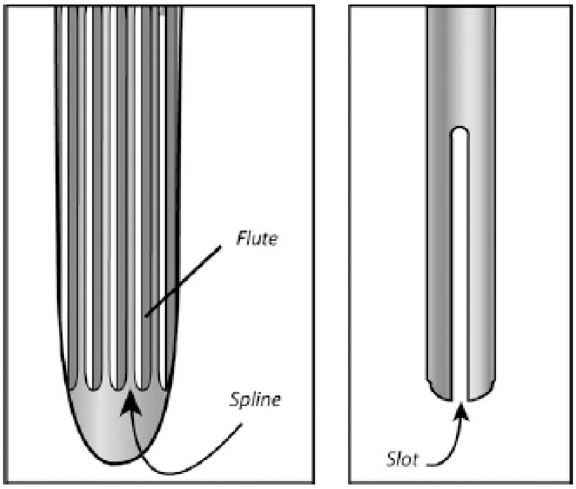


Figure 8-SPLINES AND FLUTES TO INCREASE THE ELASTIC MODULOUS AND STIFFNESS

The type II implants like their counterparts also have a circumferentially porous coating proximally.

TYPE III-

The type III stems are unique in that they have a long and consistent tapering along 2 planes (anterior-posterior & medial-lateral). They obtain fixation at the metaphysis-diaphysis junction, there is no abrupt change in the implants geometry or the coating for that matter. The type III stems can further be classified in to 3A, 3B & 3C.

Type 3A- These components are tapered, rounded and conical designs. They obtain a three point fixation and incorporate porous coating in the proximal 2/3rd through which they obtain fixation. Preparation of the canal is through standard broaches proximally and reamers distally.

For added rotational stability certain designs incorporate proximal fins or ribs.

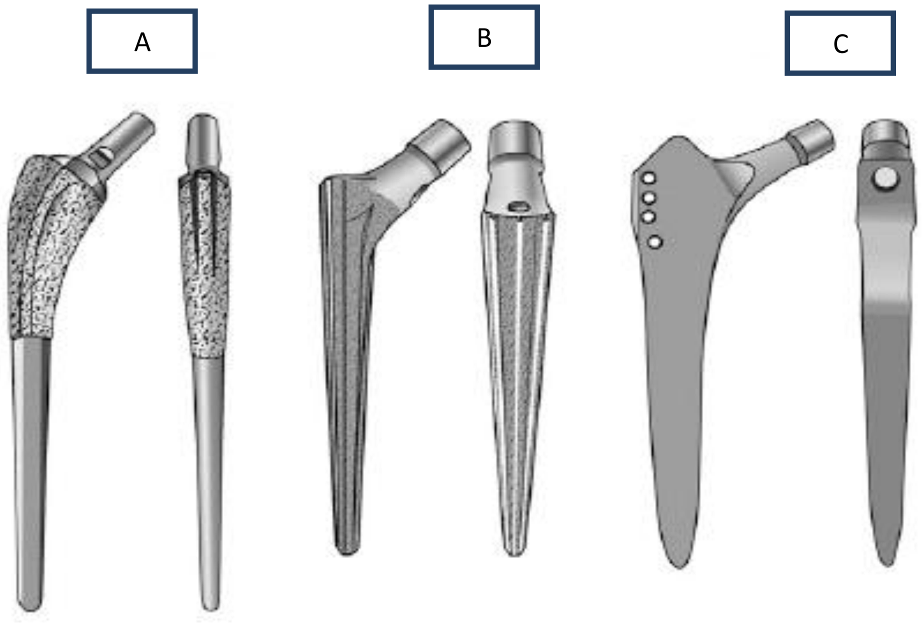


Figure 9- TYPE III-A.) TAPERED & ROUND, B.)TAPERED WITH SPLINES AND CONES, C.) TAPERED RECTANGLE

Type 3B- The 3B stems have a gradual conical taper with raised longitudinal splines for fixation. The stem has a narrow profile, equipped with sharp edges which cut in to the cancellous bone giving its added rotational stability. Although the stem is equipped with such rigid anti-rotational features, it allows good freedom of rotation as much as to control version while implanting. This uniqueness makes it a viable biological option in complex cases of distorted proximal femoral endosteum. The preparation involves use of a conical reamer to match the canal to the stem dimensions.

Type 3C- The 3C varies from its other type 3 comrades with its unique rectangular shape, gradually tapering conical stem. The stem is grit blasted along the length of it. The rectangular cross section helps to achieve a “FOUR POINT” rotational support. The rectangular configuration also achieves a three point fixation like the rest in the type III group along the medullary canal. No reaming is required for preparation, only rectangular broaches are used for canal preparation.

TYPE IV-

The type IV implant is a cylindrical fully coated implant. The entire prosthesis along its length relies on fixation with engagement of diaphyseal cortical bone. This prosthesis is also equipped with a collar proximally which engages on to the calcar also confers a certain degree of rotational stability to the implant. It employs a bone ingrowth type of surface along its length. The implant engages with the diaphysis with the so called mechanism of “SCRATCH FIT”, where in distal diameter of the prosthesis chosen must be 0.5mm larger than the last reamer used. The canal is prepared with standard proximal broaches and distal reaming, implant fixes on to the bone via bone ingrowth mechanism.

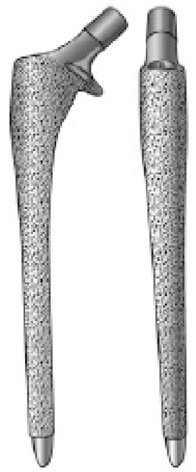


Figure 10-TYPE 4 (CYLINDRICAL & FULLY COATED)

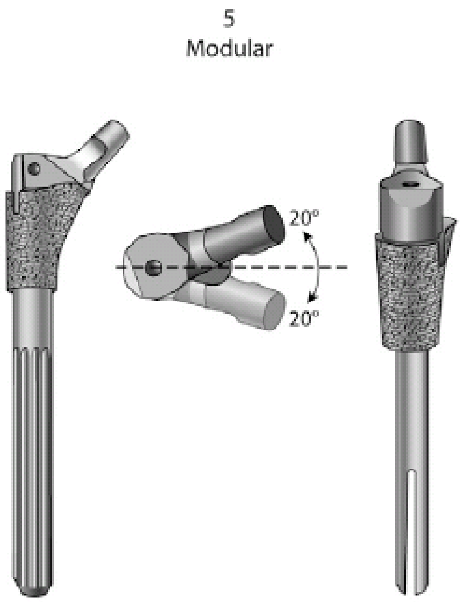


Figure 11- TYPE V MODULAR

TYPE V-

The type V prosthesis is wholly a modular anatomic prosthesis. These implants give the surgeon the freedom of choosing separate components for the metaphysis and the diaphysis. These implants are usually reserved for complex total hips or in cases of revision surgery. Fixation is obtained through a combination of proximal and distal fit of the implant. These implants come with necks which incorporate the version, so are hence side specific. The preparation for its implantation includes distal diaphyseal ream followed by machining of the metaphysis and calcar over the distal stem.

TYPE VI-

The type VI prosthesis is an anatomic prosthesis with curves that match the proximal femoral endosteum. It incorporates the proximal metaphyseal posterior bow and distal diaphyseal anterior bowing. They are wider proximally posteriorly and laterally. They are side specific stems produced with ante version incorporated necks. Two types of distal geometries are included either a tapered or cylindrical aimed at reducing the elastic modulus so as to decrease the thigh pain. The bone is prepared with usual metaphyseal broaches and distal reamers, however it is less forgiving on the endosteum as the implant matches more closely with the endosteal geometry. Stability to the implant is conferred through a proximal metaphyseal fill and distal curve for the diaphysis.

TYPES OF SURFACES& COATINGS:-

The type of surface is an important factor for inducing a proper osseo-integration to occur. Numerous modifications of surface texture have been researched. Currently the use of surface texturing in the form of grit blasting ,plasma spray ,sintering of beads or coating with hydroxyl apatite have been used. However many a times a combination of these methods are employed so as to induce biological solution of osseo-integration. The osseointegration is closely governed by the type of surface, coating and extent of texturing in the implant. Currently a circumferental coating to the proximal surface is more accepted. Earlier designs researched pads or patches of proximal coating which allowed debris of polyethylene material fluid to transport in to the distal aspect of the stem, there in causing extensive osteolysis and loosening. These extensions of joint fluid are described as the "effective joint space". On the contrary a circumferential coating in the proximal surface is said to help in the shielding of particulate debris from reservoiring in to the distal aspects of the stem.

The bone grows towards the implant surface to fix the implant & occurs via 2 mechanisms – in-growth and on-growth. In-growth surfaces are characteristically porous so as to allow the bone to grow in to the inside of a porous implant surface. There are two key factors to determining the success of any porous coated implants. In order to induce bone ingrowth in to implants, an optimum pore size of the porous implant must be between 100-400 micrometres. There must be 30-40 % void within the coating so as to maintain the mechanical stability of the implants. The ingrowth surfaces are usually manufactured by sintered bead, fibre mesh and usage of porous metals. There are 2 variants of porous coated implants, proximal porous coated & extensively porous coated.

An extensively porous coated implant is one which has porous coating up to 80 % of its surface area with an average stem length giving it reach up to the narrowest portion of the medullary canal. These are usually helpful in maintain adequate osseo-integration in both proximal and distal aspects of the stem so as to allow adequate incorporation of the implant in transmitting stresses to the bone & thereby limiting stress shielding both proximally & distally.

Figure 12- COATING SURFACES

The porous coatings on implant surface have been traditionally created by sintering beads or fibre mesh. Sintered beads use either cobalt-chromium alloy or titanium microspheres attached by using very high temperatures. Fibre mesh coatings use mesh pads which are attached to the implants via diffusion bonding technique. Regardless all techniques use high temperatures in the making, therein subjecting the underlying substrate to heating process which has a well-documented tendency towards reducing the fatigue strength of the implant. Nowadays newer materials are applied in the usage such as tantalum which was initially used for acetabular components.

On growth mechanism is described as a mechanism were in bone grows on to the roughened surface of the implant. On growth surfaces can be created either by plasma spray or grit blasting techniques. Grit blasting techniques comprises of using pressurized spray of aluminium oxide particles blasted upon the implant surface so as to create a roughened & irregular surface texture. The irregularities on the surface range from 3-8 micron meters in depth. Plasma spray technique involves usage of molten metal applied under a high velocity, in an argon gas or vacuum environment, thereby producing highly irregular & roughened surface texture for the implant surface. These procedures do not involve excessive heating of the substrate material, thereby the fatigue strength of the implant remains unaltered.

Figure 13-COATING SURFACES

HYDROXY APATITE COATINGS:-

Extensive research has been carried out in the field of implant coatings. Calcium Hydroxy-apatite is a naturally occurring calcium phosphate present in the enamel of tooth and vertebrate bone. Hydroxyl apatite coatings were first used for fixation of hip implants in 1985 by Furlong and Osborn in the United kingdom, 1986 by Geesink in Netherlands. They have reported excellent activity level, with formidable pain scores and significantly low revision rates over a period of 20 years follow-up. They have also reported hydroxyl apatite coated implants to have required lesser intimacy with the bone surface during initial implantation at surgery.

The success of the hydroxyl apatite coating was closely governed by the thickness of the coating. A thick coating was more likely to faily rather than a thin film of hydroxyl apatite coating. The thicker coatings have a tendency to delaminate from the implant interface, sometimes the thicker coatings have known to fail from within the substance of the coating notwithstanding the peak forces. Most of the current manufacturers use a coating of 50-75Âµm. the hydroxyl apatite has many advantages in itself being biocompatible & virtually benign. There is no scare of toxicity. They create an environment rich in calcium & phosphate ions locally close to the hydroxyl apatite, said to contribute to the bone ingrowth. Other forms of calcium phosphates namely amorphous dissolve more rapidly compared to the tetra calcium phosphate when compared to tri-calcium phosphate, but none superior to hydroxyl apatite in terms of rate of dissolution. The rate of dissolution in the final product of hydroxy apatite is governed by the fraction of the other variants present and crystallinity. The greater the crystallinity, greater will be the stability of the coating. However the biological activity of the coat is found to be lesser in stable coatings.

Upon implantation plate like apatite particles were visible in the low crystallinity coatings, which led to the proposed mechanism of action of these coatings. The dissolution of the calcium and phosphate ions locally produces a super saturation of these ions in the body fluid locally, thereby promoting the precipitation of carbonated apatite crystals over the implant surface. But for the successful occurrence of this mechanism is intimately dependent on the surface texture of the coating and roughness presented by it.

THE CEMENTED FEMORAL COMPONENT:-

The cemented femoral fixation mainly being the major innovation of the charnley era, has said to have undergone various modifications and refinements. Currently we have a dramatically evolved variety of cementing techniques yielding to improved implant survival and better optimization of the implants. However cemented implants are still plagued by problems or loosening and other issues related to the cementing. Various philosophies have been proposed towards the shape and make of the cemented implants.

STEM PHILOSOPHIES:-

A cemented stem must be of an optimal shape so as to adequately transmit loads which it experiences on to the cement mantle & there on to the bone itself. Numerous studies regarding the loading patterns of the implants have been studied mainly to recover the mode of failure. These implants have been constantly subjected to axial and torsional forces. Thereby creating damaging peak stresses in the cement-implant interface. The stem must therefore be designed on the perspective of addressing issues concerning adequate geometrical design, shaping so as to achieve a smooth transition of loads between the interfaces and also cementing techniques itself as a factor.

Two stem philosophies have been adopted to address these issues. There are two principle types of cemented implants-

1.) THE LOADED TAPER OR FORCE CLOSED MODEL:-

The loaded taper model has been epitomized by the Exeter implant (Stryker orthopaedics) & the CPT stem (Zimmer orthopaedics). These stems characteristically exhibit a gradual tapering in two or three planes. They become wedged in to the cement as axial loading occurs along the implant. The design offers the freedom of reducing the peak stresses in the proximal as well as the distal cement mantle. There by decreasing the stress in the cement implant / cement bone interface, where debonding occurs initially due to the peak stresses and progresses on.

These stems upon implantation subside in to the cement mantle for a certain degree until it firmly becomes wedged in, following which when the implant is loaded it converts axial loads to radial compressive forces and is transmitted through the cement mantle in to adjacent bone as hoop stresses. Usually a stem centralizer is used to allow controlled subsidence of the implant in to the stable position without creating excessive out of plane stresses in the distal mantle of cement. These stems have shown initial subsidence of .4-1.4mm in the first year, with minimal attitudes for retroversion. After initial years these stems tend to stabilize without much problems.

2.) THE SHAPE CLOSED OR COMPOSITE BEAM :-

In the composite beam concept, the stem needs to be rigidly bound to the cement without allowing any degree of subsidence. The subsidence may damage the cement and impair the stem-cement interface. Subsequently damage to the stem – cement interface will lead to formation of PMMA (poly methyl-methacrylate) or metal debris resulting in ultimate failure of the implant. These implants are designed to resist subsidence and presence of voids in the tip of the stem intended for centralizer can cause entrapment of air which may undergo thermal expansion during the curing of the cement.

This place may define the weak point in the cemented stem hence always recommended to use it with a centralizer. Studies have showed the stems working on the composite beam principle show a average subsidence of .1-.5mm in the first year. Some stems may tend to migrate in to retroversion with maximal annual subsidence recorded up to 1-2mm. Excessive or continued migration has been considered a factor for failure.

SURFACES AND FINISH OF STEM:-

Polished stems are always preferred when working with the loaded taper concept. The polished and smooth stem allows for step wise and gradual subsidence to the stable position. Even any micromotion in the stem-cement interface were to occur, there is very less production of wear debris with the polished stems. Whereas in the composite beam concept, it is considered to roughen the surface so as to optimize the stability and increase the stem-cement bonding. From the mechanical perspective a polished stem is associated with a weak cement-stem bond which has said to have a little effect on the distal, however it is considered to have higher strain patterns in the proximal mantle. But with increase in the cement stem bonding the amount of compressive forces decrease where as a trend towards a higher shear and tensile stress appears in the mantle and cement-bone interface. However polished stems are usually poorly bound and don not create these increased tensile and shear forces within the mantle. The transmission of tensile stresses relies on good cement – implant bondand the cement mantle is more vulnerable to the tensile and shear loading.[36] It is proposed that the weakly bound stem may load the mantle in a less damaging way, also for transmission of the compressive forces it is not necessary for a good bond to actually exist. Weakly bound stem transfers less shear forces and tensile stress to the cement – bone interface and is less damaging. Hence the reason behind implants with good strong cement-stem bond being sensitive to presence of incomplete and thin cement mantles with poor cement – bone interface than polished stems.

In efforts to improve the stem cement-stem interface bone pre-coating or roughening the stem has been proposed. However micro movement which eventually does of varying degrees is inevitable due to various reasons like elasticity of implants, loads (repetitive torsional, axial, compressive loads) and bone characters itself. The wear and debris production is found to be much lesser in the polished rather than the rough unpolished stems. As debonding occurs in the stem-cement interface in coated and roughened implants there is excess generation of wear particles and PMMA causing osteolysis and loosening. In Polished implants this factor occurs to a lesser degree and there is retention of the wear particles to the surface of the polished implant which shows pitting and retention of the wear particles. However in non-polished stems with wear and loosening the surfaces get grated off, especially in metals with lesser wear resistance. These unpolished stems – roughe stems require a thick and continuous cement mantle, with a good cement-bone interface in comparison to polished stems which are much tolerant to sub optimal cementing techniques also.

REVIEW OF LITERATURES ON ETHNIC DIFFERENCES IN THE PROXIMAL FEMORAL ANTHROPOMETRY:-

- **Noble P.C et al**[19] has suggested the need for describing the endosteal anthropometry for designing implants.

- A set number of somatotypes were mathematically calculated based on anatomic range of canal dimensions. The study by **Noble P.C et al**[19]consisted of 200 femora, all anthropometric parameters were evaluated. The medial and lateral wall geometry was calculated to an accuracy of +/- 1mm. through this study 45 somatotypes of implants were designed so as to match the canal dimensions of the Caucasian population. However to have 45 implants types in a replacement armamentarium is a difficult task. Out of the 45 somatotypes only 17 types occurred with an incidence of 1%. Once again there would be an armada of implants with 17 somatotypes in each replacement system. Hence the accuracy was relaxed to +/- 2mm, he was able to develop 8 somatotypes for the un-cemented replacement system. This relaxation can further be extended to +/-3mm to bring down the implant armada of the cemented system to 5 somatotypes, to address the needs of the entire population up to 95%. As the cemented system always gives more room for accommodation.

There is 8mm posterior shift of the femoral axis, hence the tip of the stem is often implanted in close apposition to the posterior cortex. He also stated that except for the anatomic implants, none of the implants take in to consideration of the posterior bow of the femur, therefore leading to impingement of stem over the anterior cortex and distal perforation of the stem. Hence the need for including posterior bow in implants and separate left and right systems.

- **Rawal et al**[42] in his study -proximal femoral anthropometric measurements of proximal femur in Indians, to design best fit implant. He described Indians and Asian population to be of smaller build and anthropometrically smaller dimensions in comparison to other ethnic groups. He compared his observations on Indian population with that of other ethnic groups estimated in various studies. He has estimated differences in femoral head offset between Indian and Swiss population of up to 16.8%, which can cause significant soft tissue tension raising the probability for a dislocation post operatively. The medio-lateral width above the lesser trochanter when compared to Caucasian population was found to have difference of 40 % , difference of 45.4% between the Indian and French population in terms of Antero-posterior canal width , indicating gross discrepancy in the fit of the implant which can result in splintering of the femur. The average canal flare index was 3-5, indicating that the Indian population favour more of a cementless type of fixation.

- **Salzer et al**[42] in his observations stated a mismatch of 10mm usually resulted in canal implant mismatch almost $1/4^{th}$ of the times. This was directly attributable to the usage of standardized implants which do not address the specificities of ethnic differences in the anthropometry. At the same time no propotional relation between the shape and size of the medullary canal can be drawn. The implants cannot be designed on the basis of proportional canal size for small and large size canal to decrease the inventory.

- **Deshmukh et al**[17] in his observations quoted on bipolar implants used in hemiarthroplasty to be available in standardized sizes according to the femoral head diameters in standard offsets to decrease the armada of implants. **Clark et al**[16]**, Greendale et al**[43] **and Crabtree et al**[44] have addressed substantial variations in the neck shaft angle and offset from person to person and ethnic differences. They have stated the variability is so vast that the commercially available implants cannot attain a fit in many of the femurs, considering vast variations it is always the bane of the Indian & Asian orthopaedic surgeons to always compromise on the fit of the implants.

- **Ramesh Kumar Sen et al**[22] in his study on the anthropometry of proximal femora using 2 modalities (radiographs and C.T. scan measurements). He described significant variations between the dimensions of Caucasian population and the Indian populations. The Indian femurs had a smaller canal dimensions especially at the proximal level in comparison to the Caucasian femurs, an average discrepancy of 4mm was noted at the three reference points (20mm above the lesser trochanter, at the level of the lesser trochanter and 20mm below the lesser trochanter). There by indicating the Indian femora to be having a smaller dimension when compared to the Caucasian femurs.

- **A.K.Mishra et al**[23] in his study on the proximal femur – a second look at rational of implant design. He had studied 50 bones (25 pairs) morphological and radiographic study was carried out to assess fit of internationally designed implants and to generate a database for proximal femur in Indian population to help in implant design. The estimated values were compared to other populations

(Chinese, Hongkong and Caucasians). His observations have shown the piriformis fossa in Indians were not in line with the intramedullary axis, the portal for antegrade I.M nail should be anterior and lateral to the pyriformis fossa. He has observed average femoral head diameters in Indians to be smaller (44.2mm) than the Caucasian populations. The trans-cervical region of the Indian population was found to be narrower than other population, hence a larger diameter cancellous screws used in fracture neck of femur has chances of causing an internal tamponade increasing the chances of AVN, or may decancellate the neck at insertion making it vulnerable to fractures.

- **D.Ravichandran et al**[24] in his study titled on proximal femoral anthropometry in Indians, has estimated the morphology of 578 paired femora and assessed variations and adequacy of fit of available implants like blade plate, dynamic condylar screw and dynamic hip screw. In his observations the femoral neck width at an average of 3.097cms, the standard Dynamic hip screw and condylar screw require reaming for the insertion of the head screw , which is 12.5mm thread length and 12.6mm barrel diameter. The reaming is done with a 11.5mm reamer and tapping with 13.5 mm tap for head screw. This process will cause removal of more than half of the precious cancellous bone stock in the proximal femur up to 1.35cms, thereby leaving it vulnerable to fractures. In other similar studies **Siwach etal**[33] have observed mean neck widths of only 2.49cms, in which case the screw will be large and occupying 2/3rds of the neck thereby causing choking of the neck with screw , may decrease the blood supply to the head of the femur increasing the chances of AVN.

MATERIALS AND METHODS

INTRODUCTION:-

This is a prospective study consisting of two fundamental parts, involved in assessing the anthropometric dimensions of the proximal femur. In the first part of the study we have evaluated anthropometry of 178 volunteers radiographically. The second part of the assessment was done with cadaveric femora obtained from the DEPARTMENT OF ANATOMY-PSG,IMSR. 50 cadaveric dry femora were obtained and direct measurement of measurable anthropometric data was done.

RADIOLOGICAL STUDY:-

INCLUSION CRITERIA-

- South Indian population
- Age 25 years and above

EXCLUSION CRITERIA-

- No prior pathology in the femur- Infection (old/healed/active),congenital anomalies, contractures& deformities around the hip, previous hip surgeries
- open epiphysis

RADIOGRAPHY TECHNIQUE:-

Volunteers were selected following which a brief counselling was given about the study and after oral consent. Antero-posterior x ray of pelvis with bilateral femur was taken with both legs internally rotated 15 degrees at the hip joint in the digital x ray device (siemens).[19,21,17] A magnification marker was kept in between the subjects thighs, in level with the femur. The cassette to tube distance was adjusted manually in the device to 100cms. The beam was centred over the symphysis of the pubis. The images were all uploaded in to the picture archiving software (PACS)

PARAMETERS TEMPLATED:-

- Femoral head diameter
- Horizontal offset
- Neck shaft angle
- Endosteal diameter at a level 20mm above Lesser trochanter (D)
- Endosteal diameter at the summit of the Lesser trochanter (E)
- Endosteal diameter at a level 20mm below the Lesser trochanter (F)

- Endosteal diameter at the level of the Isthumus (G-10 cm below lesser trochanter)
- Canal flare index
- Diameter of the ring in the magnification marker

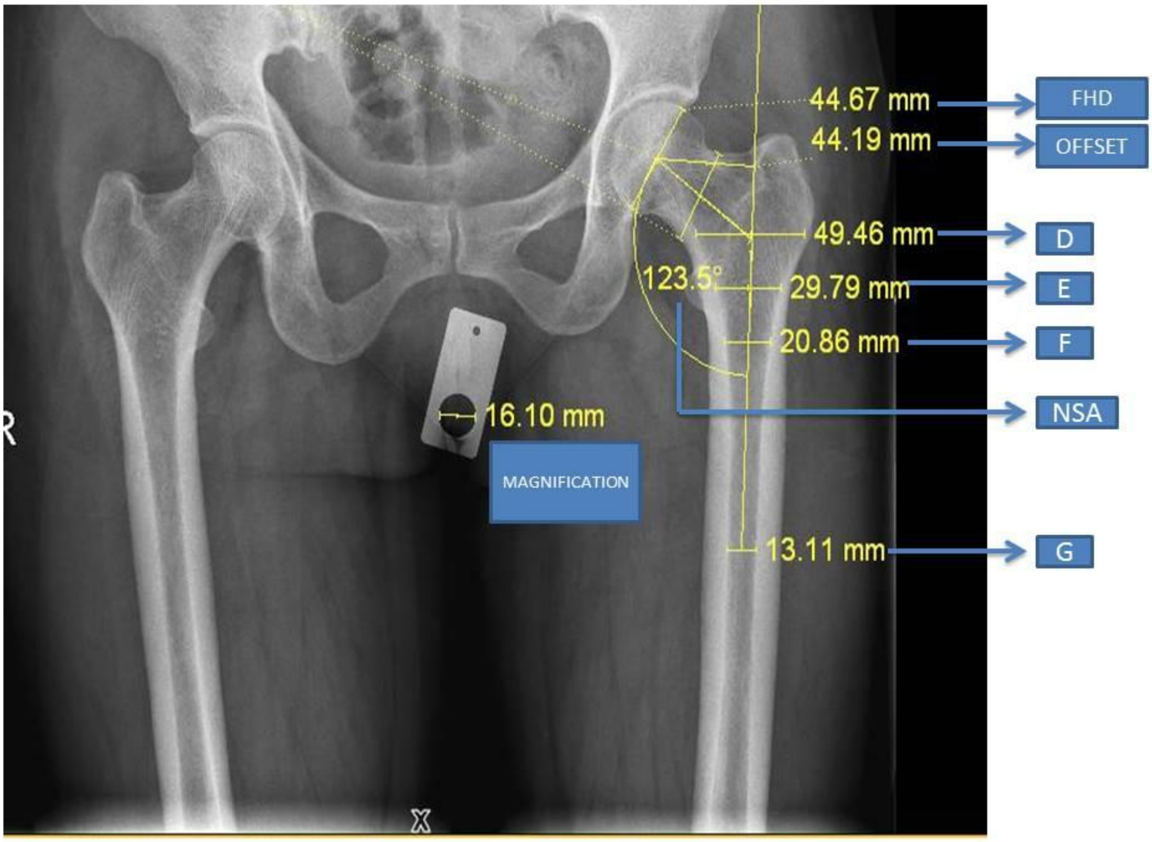


Figure 14- RADIOGRAPH TEMPLATING

METHODOLOGY OF TEMPLATING:-

ENDOSTEAL DIAMETERS:-

The endosteal width is measured at various locations based on reference lines which have been already defined as per **Noble.P.C et al .**[19,18] The apex of the lesser trochanter is taken as the first landmark. The endosteal width at the level of the apex of lesser trochanter (E), Endosteal width 20 mm above (D) and below (F) the lesser trochanter and 10cm below the lesser trochanter (G)is measured. The mid-point of these endosteal width lines are connected to form the axis of the shaft of femur. One more point is taken measuring 10cm distal to the apex of the lesser trochanter (G) which is considered as the isthumus. Endosteal width at that level is also measured.[19,21]

FEMORAL HEAD DIAMETER :-

The femoral head diameter is taken as the largest vertical diameter (superior-inferior) of head perpendicular to the axis of the neck of femur. The neck axis is drawn by drawing neck widths at 2 regions on the neck of femur, preferably in the trans-cervical and sub-capital region. The midpoints of these two lines are joined and extended further to form the axis of the neck. The Femoral head diameter is measured perpendicular to this line taking the largest superior-inferior diameter of the femoral head.[13,11,12,15,16,14,17,19,21]

HORIZONTAL OFFSET:-

The horizontal offset is also known as the actual femoral offset. The horizontal offset is measured as the distance between the centre of the femoral head to the axis of the shaft of femur. The x ray is taken in the said protocol mainly to reveal the proper and maximal offset of the femur.[17]

NECK SHAFT ANGLE:-

The neck shaft angle is the angle subtended between the shaft axis and the axis of the neck of femur.[19,17,20]

CANAL FLARE INDEX:-

The ratio between the endosteal diameters 20mm above the lesser trochanter (D) and at the level of isthumus (G) is called the canal flare index. Based on the values of canal flare index they were grouped in to normal (3-4.7) , champagne flute (high tapering in the proximal segment 4.7-6.5), stove pipe (a straight proximal femur relative to distal).[19]

The diameter of the magnification marker in the radiograph is determined for identification of the radiographic magnification error.

CADAVERIC DRY FEMORA- STUDY METHODOLOGY

The second part of the study involved with measuring the endosteal dimensions of cadaveric femur specimens. This was done to find out the true anthropometric parameters of proximal femur in addition to knowing the fit of available femoral stems, So as to determine mismatch between implant and bone if any.

In our study we have taken 50 cadaveric femora. The cadaveric femora were cut at various positions so as to ascertain the endosteal dimensions at various regions of the cadaveric femur. The femora were cut using a motorized cadaveric cutting saw in the DEPARTMENT OF ANATOMY- PSG, IMSR. The endosteal dimensions were measured using a Vernier calliper, at the regions mentioned below.

PARAMETERS MEASURED-

- Femoral head diameter
- Neck shaft angle
- Endosteal diameter 20mm above the lesser trochanter (D)
- Endosteal diameter at the level of the lesser trochanter(E)
- Endosteal diameter 20mm below the lesser trochanter(F)

- Endosteal diameter at the level of the isthmus.(G)

METHODOLOGY:-

Femoral head diameter:-

The vertical diameter (superior-inferior) of the femoral head was measured using a Vernier calliper over the largest diameter of the femoral head perpendicular to the axis of the neck.[19,24,20]

Neck shaft angle :-

The neck shaft angle was measured by the protocols as devised by **Singh and Bhasin et al**. A goniometer is used to measure the angle subtended between the neck and shaft axis. This angle will give us the colo-diaphyseal angle or the neck shaft angle.[24,25,26,27,28,29,30,19]

ENDOSTEAL DIAMETERS:-

The same landmarks were used as in the radiographic study starting from the constant point the summit of the lesser trochanter. The bone was cut along the standard reference levels using motorized saw in the DEPARTMENT OF ANATOMY –PSG IMSR. Endosteal widths at all of the reference levels were measured using a Vernier calliper as shown in the figure. (**Ramesh Kumar Sen et al** [22]**, Noble P.C et al** [19]**,Mishra et al** [23])

Figure 15-CUT SECTIONS OF DRY BONES AT VARIOUS REFERENCE LEVELS (LEFT TO RIGHT– D,E,F,G)

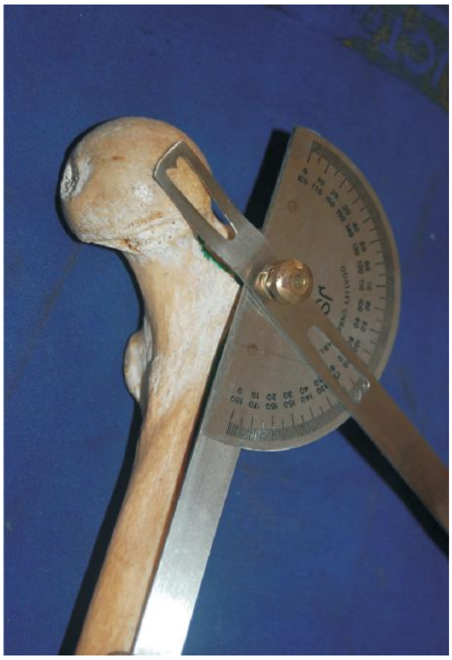


Figure 16-METHOD TO MEASURE NECK SHAFT ANGLE OF CADAVERIC DRY BONE

RESULTS&DISCUSSION

The aim of our study is to evaluate ethnic differences in the anthropometry of proximal femur of South Indians in comparison with other ethnic groups around the world.

The total population that was radiographed was 178 (n=178). There were 78 males and 100 females. The age of the participants were spaced from 25- 75 years age groups. The following parameters were measured –

Table 1- RESULTS OF RADIOGRAPHIC STUDY

Sample Size - N=178				
	Mean	**SD**	**Minimum**	**Maximum**
Age	47	10	25	75
Gender				
Male(78)				
Female(100)				
FEMORAL HEAD DIAMETER				
	47.41	4.5	35	57
MEDULLARY CANAL WIDTH				
D	43.79	5.2	33	61
E	27.35	4.3	17	43
F	19.92	3.5	12	31
G	13.88	2.8	9	23
HORIZONTAL OFFSET				
	42.75	4.3	34	53
CANAL FLARE INDEX				
	3.23	0.5	2	5
NECK SHAFT ANGLE				
	126.03	4.6	114	137

- Femoral head diameter
- Endosteal canal width 20mm above lesser trochanter (D)
- Endosteal canal width at the level of lesser trochanter (E)
- Endosteal canal width 20mm below the lesser trochanter (F)
- Endosteal canal width at the level of isthumus (G)
- Horizontal offset
- Canal flare index (CFI)
- Neck shaft angle (NSA)
- Magnification using the magnification marker.

For all the above parameters measured in 178 study subjects, mean and standard deviation were calculated.

FEMORAL HEAD DIAMETER:-

The lowest femoral head diameter measured in our study was 35 and largest femoral head diameter in the study population was 57. The mean femoral head diameter was 47.41mm with a 95% confidence interval for the mean values, a standard deviation of +/- 4.5mm. The most prevalent head size in the given population was estimated in terms of mode for the given range, was found to be 49mm.

MEDULLARY CANAL DIAMETERS:-

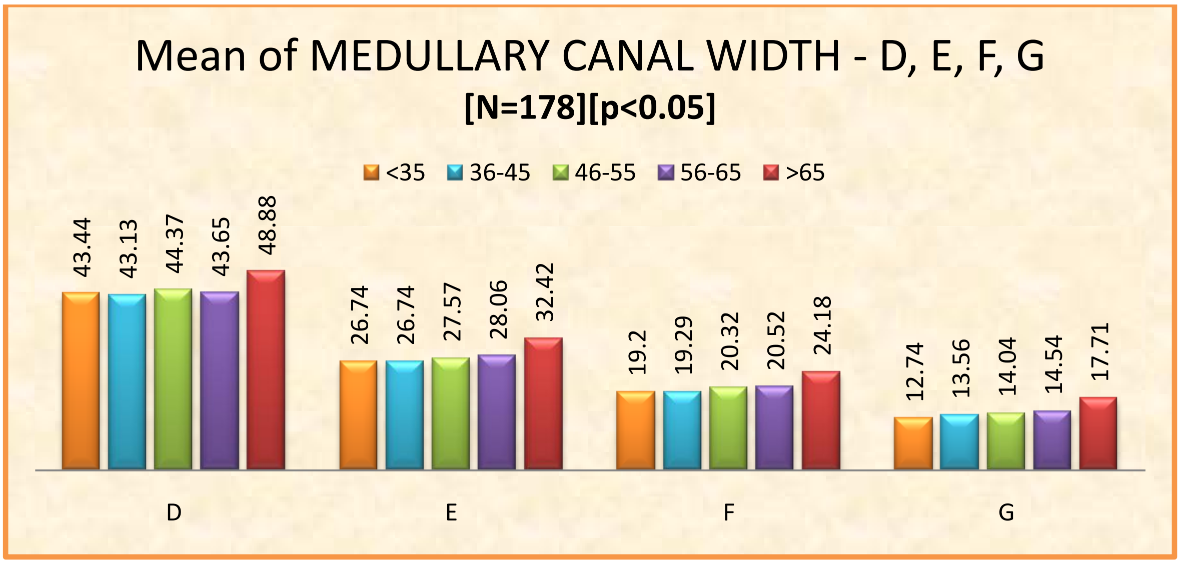
Medullary canal widths were measured at various locations on the radiographs as described earlier in correlation to the prime seating points of the femoral stem. These levels are the standard reference points to address the changing geometry of the proximal femur. The mean and standard deviations were estimated for each parameter.

MEAN CANAL WIDTHS AT REFERENCE POINTS-

- Endosteal canal width 20mm above lesser trochanter (D)- 43.79mm +/-5.2
- Endosteal canal width at the level of lesser trochanter (E)- 27.35mm +/-4.3
- Endosteal canal width 20mm below the lesser trochanter (F)- 19.92 +/-3.5
- Endosteal canal width at the level of isthumus (G)- 13.88 +/-2.8

The distribution of endosteal canal widths at various levels were analysed with their age group wise distribution.

Table 2-Mean medullary canal width at various levels matched with different age groups.



As the age groups progressed there was a tendency towards increase in the mean width of the endosteal canal diameter. This was most significant in the >65 years age groups. This was consistent with decreasing trend of canal flare index as age progressed.

CANAL FLARE INDEX:-

The canal flare index was graded in to **3 types**

1. CFI<3 as stove pipe appearance
2. 3-4.5 normal
3. >4.5 as champagne flute appearance.

The mean and standard deviation for the same was calculated. The mean CFI was found to be 3.23 +/-0.5. An age wise distribution of the canal flare index.

Table 3-AGE WISE DISTRIBUTION OF CANAL FLARE INDEX

Age Group	Stove Pipe [<3.0]	Normal [3.0 - 4.5]	Champagne	Total
<35	4	15	0	19
35-45	21	51	0	72
45-55	14	42	0	56
55-65	12	13	1	26
>65	2	3	0	5
Total	**53**	**124**	**1**	**178**
(%)	**30%**	**70%**	**1%**	**100%**

In the study population 30 % had a stove pipe appearance of medullary canal with mean CFI<3. 70 % of the population had normal appearing femora with CFI ranging from 3-4.5.

There was progressive tendency towards stove pipe appearance of femoral endosteum as age progressed. Most strikingly noted in the >65 years age group with a mean canal flare index of 2.86. The younger age groups predominantly have a more normal type of femur. The distribution was found to be statistically significant in terms of distribution with progressive decline in the endosteal dimension as age progressed, and the femoral endosteum attaining a stove pipe like appearance ($p<0.05$).

The gender wise distribution of the canal flare index was assessed, mean CFI in males was found to be 3.14 +/- 0.4, compared to the mean of 3.29 +/-0.5 in the female pool. There were statistically significant differences in the gender wise distribution of the mean canal flare index ($P<0.05$).

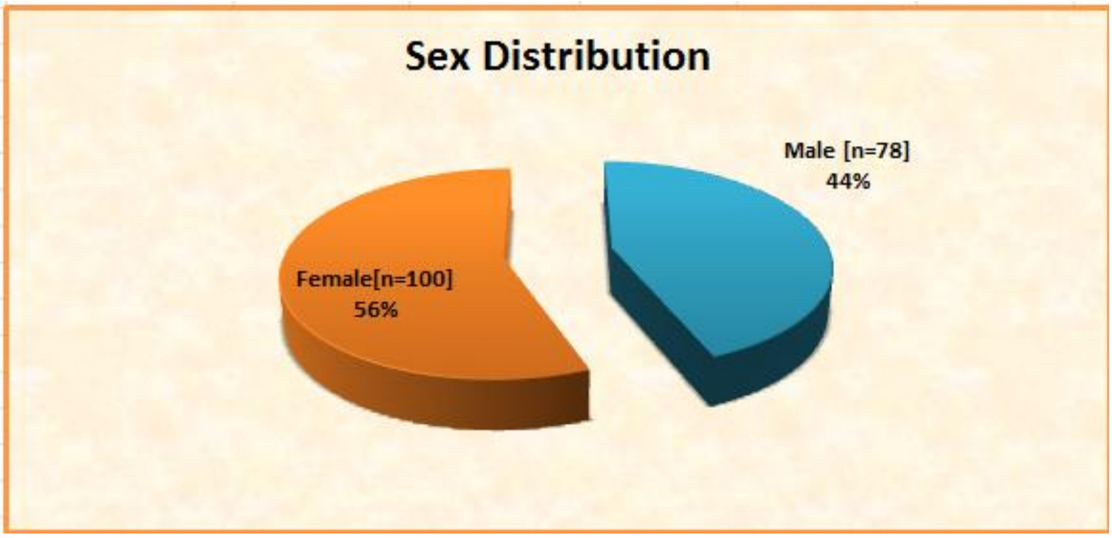
HORIZONTAL OFFSET:-

Horizontal offset calculated as the distance between the center of femoral head to the axis of the femoral shaft, which defines the abductor muscle tension was measured in all 178 subjects. The mean offset in the study population was found to be 42.75mm +/-4.3

GENDER WISE COMPARISON OF ANTHROPOMETRIC DATA:-

In there were 100 males and 78 females. The gender wise difference in anthropometric parameters measured was assessed separately for each parameter.

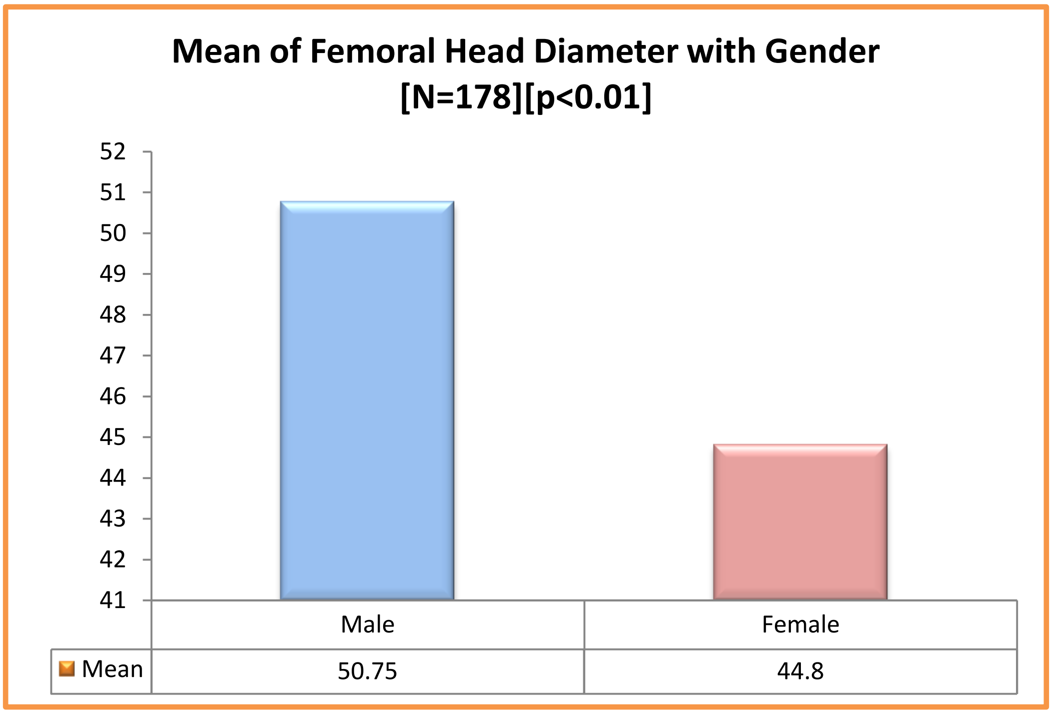
Table 4-SEX DISTRIBTUTION IN THE STUDY



FEMORAL HEAD DIAMETER:-

Mean femoral head diameter in male population was 50.75mm with standard deviation of +/- 3.7mm. Mean femoral head diameter was 44.8mm with a standard deviation of +/- 3.1mm in the female population. The mean femoral head diameters were found to be smaller in the female population in comparison to the male population. The differences between the femoral head diameters in male and female group were statistically significant ($p<0.01$).

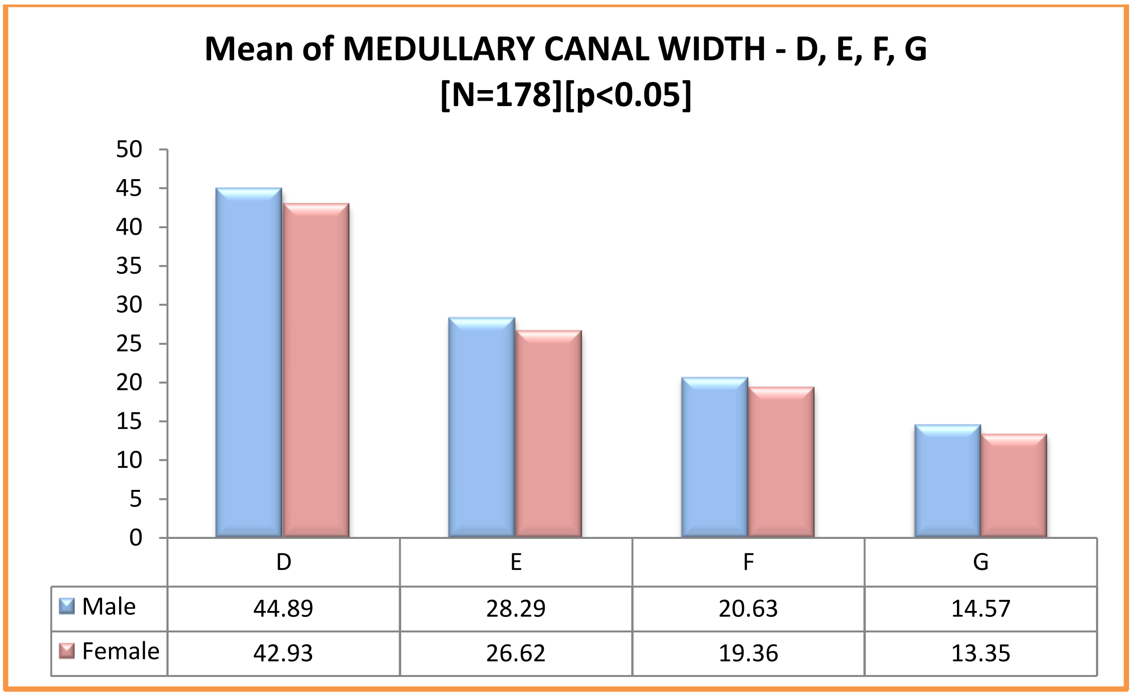
Table 5-GENDER WISE STATISTICS FEMORAL HEAD DIAMETER



MEDULLARY CANAL DIAMETERS:-

The mean endosteal diameters of male and female femora were compared for the four standard reference levels. The female femora were found to have significantly smaller mean endosteal dimensions at all the reference points in comparison to male femora. The difference was statistically significant for all the reference points ($p<0.05$). This difference in the endosteal dimensions of male and female femora is attributable to the smaller size of the femurs in the female sex.

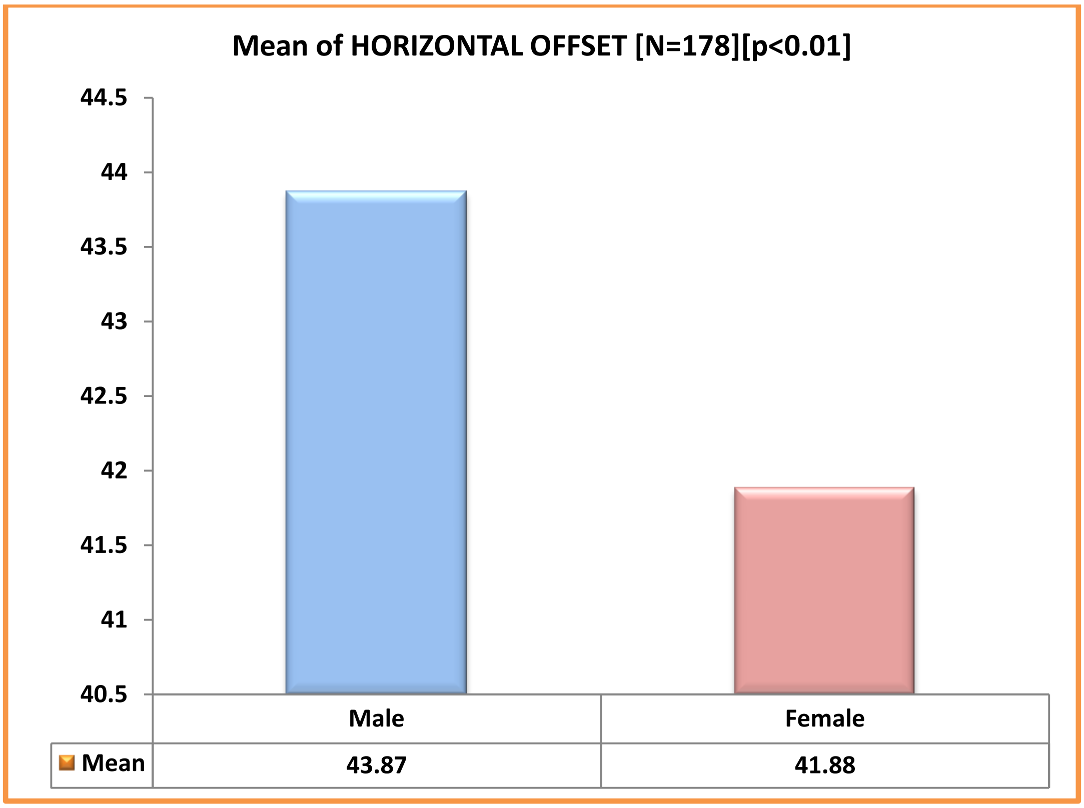
Table 6-GENDERWISE STATISTICS MEDULLARY CANAL DIAMETERS



HORIZONTAL OFFSET:-

The differences in the mean femoral offset between male and female sex was assessed. The mean femoral offset was 43.87 +/-4.4 in males, 41.88+/-4 in females. There was statistically significant differences between the 2 genders (P<0.01).The mean offset in the male gender was found to be higher in comparison to the female gender. This difference is attributable to the larger size of the male femurs.

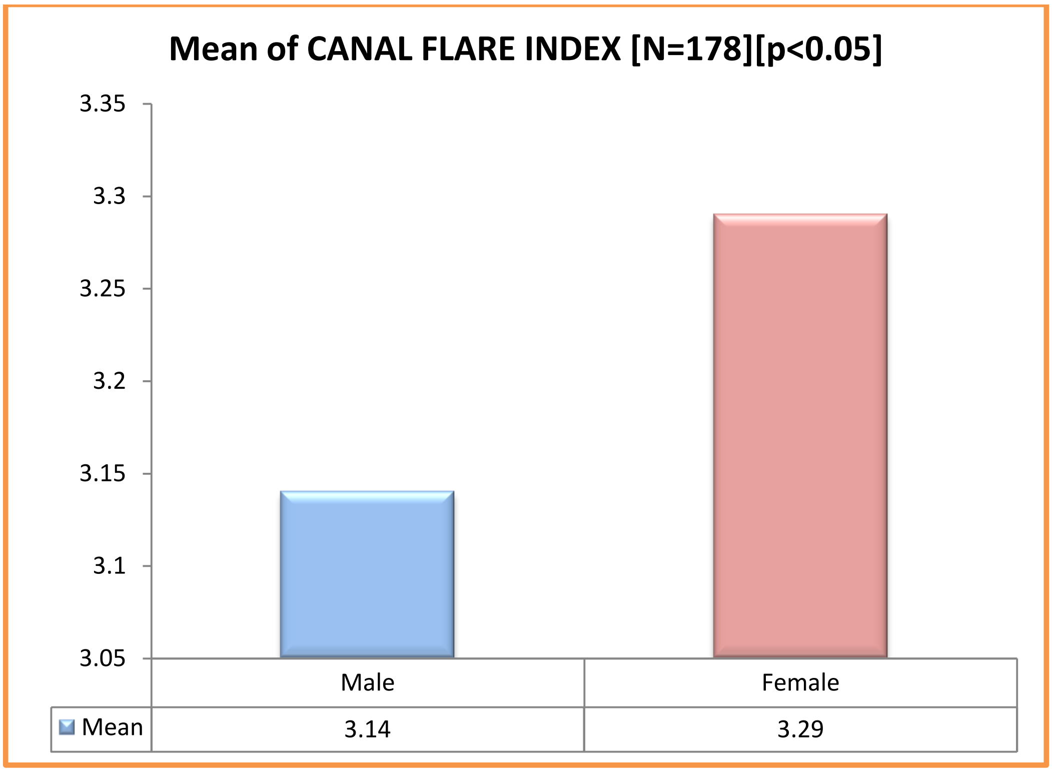
Table 7-GENDER WISE STATISTICS FOR HORIZONTAL OFFSET



CANAL FLARE INDEX:-

The gender wise distribution of the canal flare index was assessed, mean CFI in males was found to be 3.14 +/- 0.4, compared to the mean of 3.29 +/-0.5 in the female pool. There were statistically significant differences in the gender wise distribution of the mean canal flare index (P<0.05).

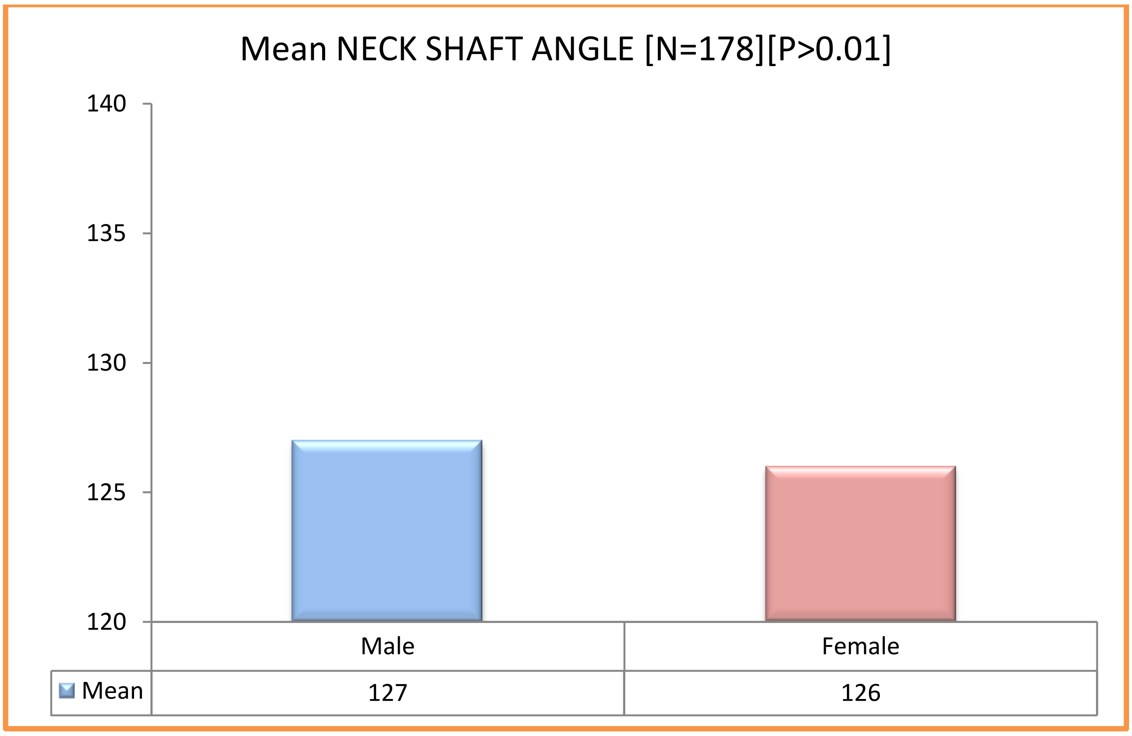
Table 8-GENDER WISE DISTRIBUTION OF CANAL FLARE INDEX



NECK SHAFT ANGLE

The mean neck shaft angle for the population was 126 degrees. The mean neck shaft angle for males was 127 degrees. The mean neck shaft angle for females was 126 degrees. There was no statistically significant difference between the neck shaft angle of male and female sex (P>0.01)

Table 9-GENDER WISE DISTRIBUTION OF NECK SHAFT ANGLE



DIFFERENCES IN ANTHROPOMETRIC PARAMETERS OF INDIAN FEMORA VS OTHER ETHNIC POPULATION:-

The ethnic differences in the anthropometry of the proximal femur was assessed by matching the values of our present study with that of values previously measured in other ethnic populations. For the comparison we have taken the values of proximal femoral anthropometry of the Caucasian population according to the study by **Noble P.C et al**[19] (n-200), the importance of this study was its vitality in bringing up of the dimensions for creation of the various somatotypes for the cemented & un-cemented replacement armamentarium. The study has allowed us to have sufficient arsenal for replacement at the same time allowing the implant to accommodate itself in to bulk of the femora. Anthropometric analysis of a Swiss population based on study by **Rubin et al**[21], Japanese population based on study by **Bo et al**[41], French population by **Massin et al**[48], Malay population by **Baharuddin et al**[20], Thai population by **Mahasavariya et al**[49].

Table 10-COMPARISON OF PARAMETERS IN PRESENT STUDY AND OTHER ETHNIC GROUPS

Other Ethnic Groups								
Study	FHD	D (20MM ABOVE	E (AT LT)	F (20MM BELOW	G(ISTHUMUS	OFFSET	CFI	NSA
Present Study (n=178)	47.16 +/- 4.5	43.79+/-5.2	27.35+/-4.3	19.92+/-3.5	13.88+/-2.8	42.75+/-4.3	3.23+/-0.5	126+/-4.6
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Rubin-Swiss (n=32)	43.4+/-2.26*	43.1+/-5.2[NS]		21.00+/-2.70[NS]	13.1+/-2.1[NS]	47+/-7.2*	3.36+/-	122.9+/-5.76*
Mahaisavariya Thai (n=108)	43.98+/-3.47*				10.50+/-1.81*			128.04+/-
Baharuddin Malay (n=60)	40.81+/-3.43*	44.05+/-4.59[NS]		18.45+/-2.93*	9.73+/-1.80*	30.35+/-4.26*		130.46+/-
Bo et al Japan (n=100)				18.00+/-3.00*	11.90+/-2.60*	31.50+/-5.00*		137.40+/-
Massin et al France (n=200)	45.60+/-4.20*	44.10+/-6.00[NS]		19.60+/-2.90[NS]	12.40+/-2.30*	41.00+/-6.20*	3.60+/-	123.10+/-8.2*
Noble (n=200)	46.1+/-4.8*	45.4 +/-5.3*	29.4 +/-4.6*	20.9 +/-3.5*	12.3+/-2.3*	43+/-6.8[NS]	3.8+/-0.74*	124.7+/-7.4*

* -> significant at 0.05 level NS-> Not significant

FEMORAL HEAD DIAMETERS:-

The difference in the femoral head diameters across various ethnic groups was assessed.

- The present study showed mean femoral head diameters in the South Indian population to be 47.16mm +/-4.5.
- The mean femoral head diameter of Indian population was compared with that of the Malay population 40.81+/-3.43mm. **Baharuddin et al**[20]
- The Malay population was found to have smallest femoral head diameters.
- The mean femoral head diameter of the present study was compared with the Thai population - 43.98+/-3.47, the Thai population had smaller femoral head dimensions. **Mahasavariya et al**[49]
- The mean femoral head diameter of the present study was compared with the Swiss population- 43.40 +/-2.26mm, the Swiss population had significantly smaller femoral head diameters **Rubin et al**[21].

- The mean femoral head diameters of the South Indian population was compared with the French population, they had lesser mean femoral head diameters- 45.60 +/- 4.20 compared to Indian population.**Massin et al**[48]

- **There was no statistically significant difference in the mean femoral head diameters between Indian and Caucasian femora-** 46.1mm +/-4.8 **Noble P.C et al**[19].

CANAL DIAMETERS :-

- The population mean endosteal dimensions were measured at four reference levels and assessed between various groups.

- The mean femoral head diameter at the four reference levels for the South Indian population was

  Endosteal diameter 20mm above lesser trochanter (D)-43.79 +/-5.2 mm

  Endosteal diameter at the level of lesser trochanter (E)- 27.35 +/- 4.3 mm

  Endosteal diameter 20mm below lesser trochanter (F)-19.92 +/- 3.5mm

  Endosteal diameter at the Isthumus (G)- 13.8 +/-2.8 mm

- There was no statistically significant difference between the endosteal diameters of South Indian and Malay population when matched against present study at the level of D (20mm above lesser trochanter) and F (20mm below the lesser trochanter). However at the level of G (isthumal diameter) it was found to be smaller in the Malay population (9.73mm +/-1.8). These differences were statistically significant. **Baharuddin et al**[20]

- There is no statistically significant difference in the mean canal diameters at the four reference levels when Indian femora were matched with the Swiss population indicating a close resemblance in terms of endosteal dimensions **Rubin et al**[21].

- There was no statistically significant difference between the endosteal diameters of the South Indian population (present study) and the French population. **Massin et al**[48]

- **The Endosteal widths of Indian femora was smaller by 2.0mm in comparison to the Caucasian femora at all 4 reference levels which was statistically significant (P<0.05).**

- Even with a magnification error of 3mm between present study and Caucasian study the endosteal dimensions are smaller by 2mm in comparison to Caucasian femora **Noble P.C et al**[19]. This suggests that the actual difference is much more.

OFFSET:-

- The mean offset in the Indian population was 42.75mm +/-4.3.

- The offset values of the South Indian population were compared with the Malay population-31.50 +/-5mm. The offset of the Malay population was found to be significantly smaller than the South Indian population **Baharuddin et al**[20].

- The offset values of the South Indian population were compared with the Japanese population – 30.45 +/- 4.26. The offset of the Japanese population was found to be significantly lower than the South Indian population **Bo et al**[41].

- The offset of the South Indian population was compared with the French population who had a mean offset of 41 +/-6.20mm. The offset of the French population was close to that of the South Indian population and the difference was not statistically significant. **Massin et al**[48]

- The offset of the South Indian population was compared with the Swiss population who had a mean offset of 47mm +/-7.2 which was the highest among the ethnic groups in study. The mean offset of the South Indian population was 4.25mm lower than the Swiss population. This probably correlates with the bigger size of the femora among European population **Rubin et al**[21].

- There is no significant difference between the offset of South Indian population and Caucasian population- 43 +/-6.8mm **Noble P.C et al**[19].

CANAL FLARE INDEX:-

- The mean canal flare index in the Indian population was found to be 3.23.

- The mean canal flare index of the South Indian population was compared to the Caucasian population which had a canal flare index of 3.8. The difference was statistically significant **Noble P.C et al**[19].

- The canal flare index of the South Indian population was compared with the French population who had a canal flare index of 3.6. The differences were found to be statistically significant between South Indian and French population, in terms of trending of the canal flare index.**Massin et al**[48]

- This probably suggests a better bone stock in the European population, with the European populations having more

Champagne flute configuration of canal flare, therefore will favour more of an Un-Cemented fixation

NECK SHAFT ANGLE:-

- The mean Neck shaft angle was found to be 126 degrees in the present study of South Indian population.

- The verge neck shaft angle of the South Indian population was compared with the Japanese population. The Japanese population had an average valgus femoral angulation with mean neck shaft angle of 137 degrees in comparison to South Indian population. **Bo et al**[41]

- The neck shaft angle of the South Indian population was compared with the Malay population. The mean neck shaft angle of the Malay population was 130 degrees. There was a slight inclination towards valgus mean femoral angulation in the Malay population when compared with the South Indian population in the present study. **Baharuddin et al**[20]

- There was no statistically significant difference between the neck shaft angles of present study and Caucasians -125 degrees **Noble P.C et al**[19].

- Analysis thus indicates more valgus femoral neck shaft angulations Asian population groups.

ASSESMENT OF ADEQUACY OF IMPLANT FIT FOR THE INDIAN FEMUR:-

The primary aim of the study was to assess the adequacy of femoral stem fit in the Indian femur. The Indian femur is considered to be smaller than the other western groups. The conventional prosthetic stems designed by most companies are not designed to fit for the smaller size of the Indian femora, hence could have an inferior fit in the Indian femora leading to problems like intra operative splintering of proximal femur upon implantation. We have measured the medio-lateral dimension of the conventionally available stems in correlation to the seating point in the proximal femur (20mm above the lesser trochanter). The measurements of the following Indian (Modular, Monoblock bipolar) and Imported stems were taken-

1. The conventional mono-block Bipolar hemiarthroplasty stems (Ormed and SMPL).
2. Indian modular (SMPL-modular)
3. Imported Modular bipolar cemented implants (Zimmer CPT-stem, De-puy)

The endosteal diameter at the level D (20mm above the lesser trochanter) was measured in all the cadaveric dry bones. The endosteal dimensions measured ranged between 31 to 48mm with a mean endosteal diameter of 39.57mm +/-4.15 at level D (20mm above the lesser trochanter). The measurement was categorized in to 'small' and 'large' group based on the range. The 'small' size group consisted of all bones with endosteal diameter ranging from 30-40mm. the large size group consisted of all bones with endosteal diameter ranging from 40-50mm.

The fit of the implant was assessed by estimating difference between the endosteal diameters at the proximal level (D) measured in cadaveric dry bones and corresponding measurement in the femoral stem of various makes.

The 'small-size stems (modular -Indian/imported)' were challenged against the bones segregatedin to the 'small' group and difference was estimated. The'large-size stems (modular -Indian/imported)' were challenged against the bones segregated in to the 'large' group and difference was estimated. The 'small' and 'large' group were both challenged with the monoblock bipolar implants (ORMED/SMPL) as the monoblock implants come in one standard size.

RESULTS CHART OF RADIOGRAPHIC STUDY:-

Sample Size - N=178				
	Mean	**SD**	**Minimum**	**Maximum**
Age	47	10	25	75
Gender				
Male(78)				
Female(100)				
FEMORAL HEAD DIAMETER				
	47.41	4.5	35	57
MEDULLARY CANAL WIDTH				
D	43.79	5.2	33	61
E	27.35	4.3	17	43
F	19.92	3.5	12	31
G	13.88	2.8	9	23
HORIZONTAL OFFSET				
	42.75	4.3	34	53
CANAL FLARE INDEX				
	3.23	0.5	2	5
NECK SHAFT ANGLE				
	126.03	4.6	114	137

IMPLANTS ASSESSMENT RESULTS CHART:-

ENDOSTEAL WIDTH 20mm ABOVE LT (D)- 39.57mm +/- 4.15		SMALL SIZE FEMORA 31 - 40 [n=29]			LARGE SIZE FEMORA 41 - 50 [n=21]		
IMPLANTS	MEDIOLATERAL WIDTH	% OF IMPLANTS NOT FITTING	% OF IMPLANTS FITTING	Mean Difference	% OF IMPLANTS FITTING	% OF IMPLANTS NOT FITTING	MEAN DIFFERENCE
DE-PUY (SIZE-1)	24	0%	100%	13			
DE-PUY (SIZE-3)	34				100%	0%	10
ZIMMER CPT (SIZE 1)	22	0%	100%	15			
ZIMMER CPT (SIZE 3)	32				100%	0%	12
SMPL (MODULAR-SMALL)	18	0%	100%	19			
SMPL (MODULAR-LARGE)	24				100%	0%	20
ORMED (BIPOLAR)	36	34%	66%	2	100%	0%	8
SMPL (BIPOLAR)	35	17%	83%	3	100%	0%	9

- In the **SMALL SIZE FEMORA GROUP** the mean difference between the **SMALL SIZE IMPLANT (MODULAR -SIZE 1)** and endosteal width at level D (20mm above lesser trochanter) was assessed.
- There was a 13mm (Depuy-size 1) and 15mm (Zimmer-size 1) for the imported implants. **The discrepancy between canal and implant size in Indian modular implant (SMPL-size 1) was much larger denoting smaller implant size with a mean discrepancy of 19mm in the small group.**
- None of the small size modular implants-size 1 (Indian/Imported) were found to have a negative difference.

Table 11-ASSESSMENT OF IMPLANT-BONE MISFIT AT THE PROXIMAL FEMUR (REFERNCE POINT D-20MM ABOVE LESSER TROCHANTER

ENDOSTEAL WIDTH 20mm ABOVE LT (D)- 39.57mm +/- 4.15		SMALL SIZE FEMORA 31 - 40 [n=29]			LARGE SIZE FEMORA 41 - 50 [n=21]		
IMPLANTS	MEDIOLATERAL WIDTH	% OF IMPLANTS NOT FITTING	% OF IMPLANTS FITTING	Mean Difference	% OF IMPLANTS FITTING	% OF IMPLANTS NOT FITTING	MEAN DIFFERENCE
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SMPL (MODULAR-SMALL)	18	0%	100%	19			
SMPL (MODULAR-LARGE)	24				100%	0%	20
ORMED (BIPOLAR)	36	34%	66%	2	100%	0%	8
SMPL (BIPOLAR)	35	17%	83%	3	100%	0%	9

- In the **LARGE SIZE FEMORA GROUP** the mean difference between the **LARGE SIZE IMPLANT (MODULAR -SIZE 3)** and endosteal width at level D (20mm above lesser trochanter) was assessed.

- There was a mean difference of 10mm (Depuy-size 3) and 12 (Zimmer size 3) for imported implants.

- **The discrepancy between canal and implant size in Indian modular implant large size (SMPL-SIZE 3) was much more stating much smaller implant size with a mean discrepancy of 20mm in the large group.**

- None of the large size modular implants-size 3 (Indian/Imported) were found to have a negative difference.

- The bipolar mono-block implant had significant discrepancies when matched with the small group with only 3mm (SMPL) & 2mm (ORMED) mean difference, indicating a very tight fit for the bipolar implants.

- **The SMPL bipolar implant was found to have a negative difference in 17 % of the medullary canals.The ORMED bipolar was found to have a negative difference in 34% of the medullary canals**.

- The intra operative splintering at the level of proximal femur (above the lesser trochanter) which commonly occurs with the use of Monoblock Bipolar implants can be attributed to the implant being larger for our population.
- **Over all the majority of the femurs fall in the smaller category 60% (29) with Indian bipolar mono-block stems seen to be a very tight fit (2-3mm difference only) and larger than the medullary canal dimension at level D.**

CONCLUSION

- In our study the comparison of average measurements in male and female femora. The male femora had larger dimensions in all the anthropometric parameters.
- The canal flare index in South-Indians was an average of 3.23 with 70% of the study population having normal CFI (3-4.5), 30% of the population having a stove pipe configuration CFI (<3). Majority of the Indian population favour a un-cemented fixation (70%).
- The Canal flare index was found to be decreasing with age which is in correlation to the age related decrease in the femoral bone stock.
- Significant anthropometric differences exist in the anthropometry of proximal femur between various ethnic populations.
- The Asian and Indian femur bone is of much smaller sizes in comparison to European femurs.
- At the neck osteotomy (level-D) the mean canal-implant difference was 2-3mm for all mono-block bipolar implants indicating a very tight fit.

- The implant was found to be oversized in 17% (SMPL) and 34% (ORMED) of the femurs. Thus accounting for the regular occurrence of proximal splintering with the use of the implant.
- In summary all current implants have to be revised on population basis to fit the changing anthropometry of our proximal femur.

LIMITATIONS OF STUDY:-

- The radiographic study had a mean magnification of 3mm.
- There was radiation exposure to normal subjects who have volunteered for the study
- The age of the dry bones was not available

BIBLIOGRAPHY

1.) Charnley, J.: Anchorage of the femoral head prosthesis to the shaft of the femur. J Bone Joint Surg Br, 42-B: 28-30, 1960.

2.) Charnley, J.: The Lubrication of animal joints. In Symposium onBiomechanics, pp. 12-22. Edited, 12- 22, Institution of Mechanical Engineers, 1959.

3.) Charnley, J.: Arthroplasty of the hip: A new operation. Lancet, I: 1129-1132, 1961.

4.) Pablo Gomez et al . The historical and economic prespective on sir john charnley. Iowa orthopaedic journal vol-25, 30-37.

5.) Charnley et al. low friction arthroplasty of the hip: Theory and practice. Berlin , springer 1979.

6.) Getz B et al. The hip joint in Lapps. Acta Orthoi Scand (Suppl 22) 1955

7.) Steindler A et al. Mechanics of Normal and Pathological Locomotion in Man. Charles C Thomas, Springfield IL, 1935

8.) Von Lanz T et al. Anatomische und entwicklungsgeschichtliche Probleme am Huftgelenk. Verhandlungen der Deutschen Orthopadischen Gesellshaft 37:7, 194

9.) McKibbin B et al. Anatomical factors of the hip joint in the newborn. J Bone Joint Surg (Br 52:148, 1970

10.) Kate B.R et al 1976, Acta Anat., 94 (1976) 457.

11.) Kay et al, 2000. The effect of femoral rotation on the projected femoral neck shaft angle.J.pediatric orthop.,20:736-739.

12.) Maheshwari et al,2004. Estimation of the femoral neck anteversion in adults- a comparison between preoperative ,clinical and biplane x rays method. Indian j.orthop.,38:151-157.

13.) Mc gory et al,1995. Effect of femoral offset on range of motion and abductor muscle strengthafter total hip arthroplasty.j.bone and joint surgery.,77:865-869.

14.) Fletcher et al,2007.three dimensional custom designed femoral stem for osteoarthritis secondary to congenital dislocation of hip.j.bone joint surg.Br.,89-b:1586-91.

15.) Jain et al,2005. Femoral neck anteversion : A comprehensve indian study. Indian journal of orthop, 39:137-14.

16.) Clark et al.1987. The relationship of neck orientation to the shape of the proximal femur . J.arthroplasty,2:99-109.

17.) Deshmukh et al,2010. Prediction of femur bone geometry using anthropometric data of indian population : A numerical approach.J.med .sci 10(1):12-18 –january.

18.) Bulent atilla et al, 2007. Acta orthop traumatol turc 2007; 41(1):64-68.

19.) Pphillip .c. noble et al, 1988 october.clincial orthopedics and related research-235.

20.) Baharuddin et al, 2011. Morphology study of the proximal femur in malay population.Int.j.morphology 29(4):1321-1325,2011.

21.) Rubin et al,1992. The morphology of proximal femur – a three dimensional radiographic analysis. J.bone joint surgery (Br) 1992; 74-B:28-32.

22.) Ramesh Kumar Sen et al, 2010. Proximal femoral medullary canal diameters in Indians: correlation between anatomic, radiographic, and computed tomographic Measurements. Journal of Orthopaedic Surgery 2010;18(2):189-94.

23.) AK Mishra et al, 2009. The proximal femur –a second look at rational of implant design. Nepal Med Coll J 2009; 11(4): 278-280.

24.) D.Ravichandran et al, 2011. The proximal femoral geometry in Indians and its clincial applications. J.anat .soc.ind. 60(1):6-12 (2011).

25.) Singh and Bhasin et al. anthropometry 1st edn. Delhi , educational publishers and book sellers, 1968-pp 142.

26.) Parsons P.G . The characteristics of the English thigh bone. J.anat and physio-1914; 48 : 238-267.

27.) Kate B.R, 1967. The angle of the femoral neck in Indians , eastern anthropologists 1967; 20: 54-60.

28.) Humphrey et al,1958.the angle of neck with the shaft of the femur at different periods of life and at different circumstances. J.anat and physio;1958 -23:273.

29.) Issac et al , 1993. The neck shaft angle of the femur .Vellore: Tamilnadu Dr. MGR university , india.

30.) Chauhan et al,2002. The anatomic parameters of the north indian hip joint- a cadaveric study. J.anat soc india 2002; 51:39-42.

31.) Eckhoff et al (1994).

32.) Pauwells et al, 1980. Biomechanics of the locomotor apparatus. Springer verlag, newyork,pp 1-228.

33.) Siwach et al Anthropometric study of the proximal femur geometry and its clinical applications. Indian journal of orthopaedics 2003; 37(4):247-251

34.) Pilliar, R. M., Lee, J. M., and Maniatopoulos, C.: Observations on the effect of movement on bone ingrowth into porous-surfaced implants. Clin.Orthop. 208: 108, 1986

35.) Reichelt and Blasius et al 1984. First experience with the PM prosthesis.In morscher E (ed) : The cementless fixation of the hip endoprosthesis. Network,springer verlag P.181.

36.) Crowninshield et al., 1983. A stress analysis of acetabular reconstruction in protrusio acetabuli. J Bone Joint Surg 1983; 65A:495.

37.) Davey et al., 1993. Femoral component offset: its effect on strain in bone- cement. J Arthroplasty 1993; 8:23.

38.) Brand et al., 1994. Comparison of hip force calculations and measurements in the same patient. J Arthroplasty 1994; 9:45

39.) Barrack et al., 2001. The effect of component design on range of motion to impingement in total hip arthroplasty. Instrictional Course Lectures- 2001; 50:275.

40.) Burroughs et al., 2005. Range of motion and stability in total hip arthroplasty with 28-, 32-, 38-, and 44-mm femoral head sizes: an in vitro study. *Journal of arthroplasty* 2005; 20:11.

41.) Bo A, Imura S, Omori H, Okumura Y, Ando M, Baba H, White P, Zarnowski A: Fit and fill analysis of a newly designed femoral stem in cementless total hip arthroplasty for patients with secondary osteoarthritis. J Orthop Sci 1997,2:301–312.

42.) Salzer M, Knahr K, Locke H, Stärk N. Cement-Free Bioceramic Double-Cup Endoprosthesis of the Hip-Joint. Clinical Orthopaedics and Related Research 1978;134:80-86.

43.) Greendale et al., 2003.Hip axis length in mid-life Japanese and Caucasians U.S residents: No of evidences for ethnic difference. Osteoporos Int.,14:320-325.

44.) Crabtree et al., 2000. Hip geometry, bone mineral distribution and bone strength in European men and women. The EPOS study.Bone., 27: 151-159.

45.) Berry, 1999. Berry DJ: Total hip arthroplasty in patients with proximal femoral deformity. Clin Orthop Relat Res 1999; 369:262.

46.) Bateman, 1974. Bateman JE: Single-assembly total hip prosthesis preliminary report. Orthop Dig 1974; 2:15.

47.) Giliberty et al., 1978. A retrospective study of the bipolar hip endoprosthesis. Orthop Rev 1978; 7:27.

48.) Massin P, Geais L, Astoin E, Simondi M, Lavaste F: The anatomic basis for theconcept of lateralized femoral stems: a frontal plane radiographic study of the proximal femur. J Arthroplasty 2000, 15(1):93–101.

49.) Mahaisavariya B, Sitthiseripratip K, Tongdee T, Bohez ELJ, Vander Sloten J, Oris P:Morphological study of the proximal femur: a new method of geometricalassessment using 3-dimensional reverse engineering. Med Eng Phys 2002,24(9): 617–622.

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SMPL (BIPOLAR)	35	17%	83%	3	100%	0%	9

CADAVERIC FEMORA MASTER CHART

S.No	FHD	MEDULLARY CANAL WIDTH				NSA
		D	E	F	G	
1	47	44	32	24	14	128
2	44	40	29	21	13	125
3	49	45	31	26	13	130
4	46	41	26	22	12	127
5	39	35	22	17	10	135
6	43	41	24	21	12	118
7	46	43	25	18	12	125
8	41	39	23	17	9	127
9	52	48	39	25	16	128
10	48	44	30	21	11	130
11	51	47	40	27	17	130
12	40	35	24	18	12	125
13	44	40	27	19	13	126
14	43	38	22	18	11	127
15	46	41	28	15	8	135
16	42	36	21	16	9	115
17	45	42	26	17	8	120
18	49	45	30	20	13	122
19	47	44	31	21	12	127
20	50	46	38	25	15	128
21	44	41	26	18	13	127
22	43	39	26	18	12	126
23	41	37	22	16	10	130
24	37	32	25	18	9	135
25	42	38	27	19	10	133
26	43	39	24	15	11	132
27	45	40	28	17	8	129
28	38	33	23	15	10	126
29	35	31	21	14	7	131
30	44	40	27	20	14	130
31	47	43	31	23	16	128
32	48	42	29	20	15	125
33	43	38	25	18	13	127
34	38	35	22	17	12	130
35	37	32	23	16	13	131
36	41	37	23	16	10	135
37	42	37	22	14	10	125
38	45	40	26	19	11	127
39	40	37	25	18	12	126
40	43	38	24	17	11	133
41	43	44	30	21	11	127
42	42	42	24	16	11	128
43	41	35	20	13	10	125
44	40	44	31	19	11	125
45	44	45	30	22	10	125

S.No	FHD	MEDULLARY CANAL WIDTH				NSA
		D	E	F	G	
46	39	36	21	14	7	125
47	43	40	24	17	9	120
48	38	31	23	14	8	125
49	45	48	30	15	7	130
50	34	35	20	13	9	125

RADIOGRAPHIC STUDY MASTER CHART

S.NO	AGE / SEX	FEMORAL HEAD DIAMETER	MEDULLARY CANAL WIDTH				HORIZONTAL OFFSET	CANAL FLARE INDEX	NECK SHAFT ANGLE	MAGNIFICATION
			D	E	F	G				
1	40/F	44.67	49.46	29.79	20.86	13.11	44.19	3.7	123	16.1
2	50/f	53.28	53.72	34.03	23.87	17.31	44.89	3.1	130	16.7
3	46/f	43.57	44.88	27.78	19.23	10.15	36.9	4.2	131	16.87
4	34/m	45.06	46.69	35.02	23.37	15.17	43.76	3.07	130	17.59
5	55/m	50.98	48.28	30.59	23.25	15.9	42.91	3.03	124	16.47
6	38/f	41.26	33.48	21.77	15.64	9.5	40.29	3.52	123	16.67
7	51/f	42.08	42.46	24.43	15.71	15.13	42.46	2.8	123	16.86
8	32/f	46.52	48.29	29.44	21.78	16.47	40.66	2.93	127	17.64
9	42/f	51.86	59.68	37.51	26.71	17.63	51.73	3.38	124	16.52
10	44/f	47.3	42.37	26.22	19.68	14.32	40.53	2.95	130	17.17
11	38/f	44.09	47.29	22.49	16.15	13.28	43.26	3.56	121	17.31
12	60/f	41.46	47.15	26.19	14.55	9.9	40.46	4.7	122	17.48
13	35/f	46.17	45.29	28.38	19.08	13.62	37.74	3.32	125	16.86
14	50/m	51.09	47.68	31.59	24.44	16.68	43.5	2.85	134	16.68
15	55/f	45.54	43.78	26.85	22.77	15.77	45.61	2.77	121	16.92
16	37/f	42.72	47.72	29.06	21.53	12.8	38.42	3.72	130	16.3
17	53/f	42.95	39.92	26.22	21.44	15.53	37.69	2.57	124	17.22
18	48/f	47.25	47.96	26.49	20.85	13.5	41.22	3.55	124	17.38
19	42/f	47.32	45.16	25.47	18.53	12.17	37.66	3.71	132	17.36
20	50/f	44.7	42.72	26.85	18.91	12.81	40.9	3.33	125	16.47
21	42/f	45.17	50.24	26.61	20.12	13.64	42.62	3.68	128	16.54
22	36/m	52.3	44.19	26.91	20.29	13.16	41.76	3.35	129	16.6
23	46/f	42.33	42.9	25.62	20.26	15.49	39.34	2.76	126	16.69
24	39/f	46.43	47.97	29.42	19.15	13.76	44.42	3.48	118	16.69
25	45/m	55.87	38.32	24.28	17.81	15.1	44.26	2.53	135	17.26
26	64/f	46.64	43.58	29.63	21.5	13.96	37.8	3.12	129	16.27
27	43/f	41.85	39.69	25.2	16.85	12.64	42.81	3.14	129	16.69
28	30/f	42.39	35.95	17.09	11.79	8.84	43.03	4.06	121	16.5
29	69/m	48.46	47.89	30.37	22.19	15.18	48.02	3.15	120	16.95
30	37/m	46.62	44.03	23.76	15.45	12.45	41.89	3.53	133	17.18

S.NO	AGE / SEX	FEMORAL HEAD DIAMETER	MEDULLARY CANAL WIDTH				HORIZONTAL OFFSET	CANAL FLARE INDEX	NECK SHAFT ANGLE	MAGNIFICATION
			D	E	F	G				
31	43/m	52.1	44.24	26.54	20.46	13.28	40.94	3.33	124	16.03
32	54/m	56.63	43.83	27.64	21.07	13.82	52.25	3.17	121	16.69
33	45/m	49.79	39.42	21.76	13.53	10.6	46.57	3.71	124	16.47
34	60/f	48.79	46.57	32.43	26.91	18.47	45.95	2.52	122	16.47
35	30/m	52.03	39.05	26.23	20.13	12.81	39.68	3.04	131	16.47
36	45/f	41.51	39.05	23.18	17.08	10.98	33.56	3.55	134	17.7
37	58/f	43.52	47.7	30.41	19.67	11.98	41.27	3.98	130	17.28
38	63/f	44.83	38.9	25.14	17.92	13.16	36.66	2.95	131	16.68
39	55/f	44.9	40.14	24.2	17.72	12.39	36.71	3.23	121	17.13
40	42/m	50.52	37.13	22.98	16.5	10.61	42.63	3.49	128	17.09
41	46/m	49.76	46.63	26.29	19.62	13.51	47.67	3.45	122	17.4
42	27/f	40.27	39.62	25.32	18.86	10.01	40.38	3.95	133	16.39
43	50/m	44.69	42.27	27.17	19.19	13.84	42.59	3.05	124	16.7
44	46/m	57.11	50.09	32.11	21.79	15.79	44.15	3.17	127	16.86
45	50/m	55.05	50.65	35.76	29.8	22.65	46.61	2.23	129	16.09
46	27/m	53.76	61.21	42.73	30.61	18.48	38.8	3.31	130	16.69
47	38/f	44.87	40.82	22.48	17.61	11.83	39.67	3.45	123	16.56
48	40/f	44.56	44.44	30.92	20.42	15.12	43.15	2.93	128	16.82
49	53/f	44.65	44.24	26.43	20.11	12.65	35.63	3.49	127	16.67
50	47/f	46.64	45.68	23.1	17.73	11.28	41.58	4.04	123	16.74
51	51/m	50.27	41.71	26.82	18.48	12.53	51.46	3.32	120	16.69
52	26/m	43.12	40.64	21.79	15.9	10	39.62	4.05	130	17.09
53	45/f	40.69	36.02	23.04	15.36	10.67	35.26	3.37	124	15.91
54	53/m	40.35	38.7	21.12	15.83	11.14	34.61	3.47	127	17.59
55	49/m	54.49	44.59	27.94	20.01	15.47	53.12	2.88	122	17.25
56	63/m	48.51	38.85	25.31	18.84	13.54	38.25	2.86	126	15.9
57	60/m	45.45	41.91	26.96	20.95	11.37	43.83	3.68	130	16.15
58	51/m	51.07	41.64	28.84	20.29	12.81	41.63	3.25	137	17.61
59	47/f	40.49	35.77	18.76	14.66	11.14	37.53	3.21	124	17.01
60	42/m	50.21	41.13	25.63	19.06	11.91	45.95	3.45	128	16.05
61	31/f	42.67	47.42	24.28	18.94	12.45	42.73	3.8	126	15.39
62	42/m	50.73	50	30.22	20.92	13.37	49.64	3.73	123	16.26

S.NO	AGE / SEX	FEMORAL HEAD DIAMETER	MEDULLARY CANAL WIDTH				HORIZONTAL OFFSET	CANAL FLARE INDEX	NECK SHAFT ANGLE	MAGNIFICATION
			D	E	F	G				
63	45/f	43.43	41.74	28.21	22.36	16.59	38.87	2.51	124	17.2
64	42/f	42.98	41.71	26.22	19.06	13.12	40.54	3.71	131	16.69
65	55/f	45.51	39.5	25.55	20.91	14.52	37.79	2.7	131	16.26
66	50/f	43.19	48.24	31.17	20.01	13.53	41.24	3.56	129	16.45
67	44/m	50.31	41.52	24.32	17.2	14.84	51	2.79	125	16.61
68	40/f	48.2	45.87	26.46	20	11.76	45.42	3.9	130	15.88
69	36/f	42.26	41.27	26.45	20.63	11.65	38.61	3.54	126	16.4
70	46/f	42.66	38.28	21.21	14.72	11.19	42.4	3.42	118	17.67
71	37/m	50.05	46.36	30.5	22.32	15.27	46.05	3.03	130	16.99
72	61/m	53.08	42.8	23.14	17.38	15.65	44.87	2.73	123	16.27
73	51/m	46.27	46.4	27.37	20.22	14.26	42.94	3.25	127	17.23
74	40/f	49.86	49.76	30.08	26.06	18.96	46.24	2.62	125	16.6
75	47/f	44.14	39.31	23.83	17.27	10.72	36.95	3.66	123	16.72
76	39/f	43.47	42.26	28.16	19.36	12.92	41.69	3.35	129	16.44
77	45/m	51.31	45.24	24.09	18.21	11.61	37.77	3.89	134	16.46
78	47/f	43.37	44.02	27	21.31	14.1	43.4	3.12	130	17.02
79	40/m	53.13	37.02	23.14	15.62	11.57	42.23	3.19	131	17.36
80	30/f	44.84	44.6	28.61	21.61	12.25	44.99	3.64	120	16.85
81	39/m	49.15	39.33	26.22	20.27	17.88	36.96	2.19	129	16.69
82	50/m	53.28	53.72	34.03	23.87	17.31	44.89	3.1	130	16.7
83	33/f	47.43	33.39	21.06	15.74	11.64	42.46	2.86	123	16.86
84	26/m	50.87	40.58	25.51	16.52	14.49	34.56	2.8	135	16.79
85	37/f	41.77	35.07	21.44	14.21	10.64	37.1	3.29	122	17.05
86	50/f	45.46	46.49	30.63	22.39	13.56	45.83	3.42	121	16.46
87	37/f	42.92	41.22	26.25	18.51	13.76	35.07	2.99	130	16.69
88	41/m	48.18	48.96	31.05	23.29	14.33	43.58	3.41	127	17.31
89	40/m	53.1	43.52	28.62	20.27	16.1	43.59	2.7	128	16.69
90	45/m	51.76	41.17	28.97	24.34	17.41	44.19	2.36	130	16.21
91	43/m	52.1	44.24	26.54	20.46	13.28	40.94	3.31	124	16.03
92	50/m	56.05	51.28	32.77	25.72	23.22	50.44	2.22	121	16.59
93	44/f	45.89	47.98	30.04	22.54	15.03	43.46	3.19	123	16.17
94	50/m	52.71	45.85	31.35	23.22	16.84	47.1	2.72	126	17.42

S.NO	AGE / SEX	FEMORAL HEAD DIAMETER	MEDULLARY CANAL WIDTH				HORIZONTAL OFFSET	CANAL FLARE INDEX	NECK SHAFT ANGLE	MAGNIFICATION
			D	E	F	G				
95	50/m	55.67	49.7	32.52	22.48	16.02	44.7	3.1	132	17.11
96	38/m	47.19	43.93	28.7	21.68	15.26	46.18	2.87	128	16.4
97	34/f	46.62	39.96	21.51	15.13	11.79	48.86	3.38	120	16.2
98	42/f	41.14	34.08	20.43	11.91	9.65	41.68	3.53	130	16.44
99	38/F	44.67	49.46	29.79	20.86	13.11	44.19	3.7	123	16.1
100	56/m	53.28	53.72	34.03	23.87	17.31	44.89	3.1	130	16.7
101	46/f	43.57	44.88	27.78	19.23	10.15	36.9	4.2	131	16.87
102	40/m	45.06	46.69	35.02	23.37	15.17	43.76	3.07	130	17.59
103	59/m	50.98	48.28	30.59	23.25	15.9	42.91	3.03	124	16.47
104	45/f	41.26	33.48	21.77	15.64	9.5	40.29	3.52	123	16.67
105	56/f	42.08	42.46	24.43	15.71	15.13	42.46	2.8	123	16.86
106	40/f	46.52	48.29	29.44	21.78	16.47	40.66	2.93	127	17.64
107	45/f	51.86	59.68	37.51	26.71	17.63	51.73	3.38	124	16.52
108	47/f	47.3	42.37	26.22	19.68	14.32	40.53	2.95	130	17.17
109	55/m	50.27	41.71	26.82	18.48	12.53	51.46	3.32	120	16.69
110	30/m	43.12	40.64	21.79	15.9	10	39.62	4.05	130	17.09
111	50/f	40.69	36.02	23.04	15.36	10.67	35.26	3.37	124	15.91
112	57/m	40.35	38.7	21.12	15.83	11.14	34.61	3.47	127	17.59
113	53/m	54.49	44.59	27.94	20.01	15.47	53.12	2.88	122	17.25
114	60/m	48.51	38.85	25.31	18.84	13.54	38.25	2.86	126	15.9
115	58/m	45.45	41.91	26.96	20.95	11.37	43.83	3.68	130	16.15
116	54/m	51.07	41.64	28.84	20.29	12.81	41.63	3.25	137	17.61
117	45/f	40.49	35.77	18.76	14.66	11.14	37.53	3.21	124	17.01
118	45/m	50.21	41.13	25.63	19.06	11.91	45.95	3.45	128	16.05
119	32/f	44.84	44.6	28.61	21.61	12.25	44.99	3.64	120	16.85
120	41/m	49.15	39.33	26.22	20.27	17.88	36.96	2.19	129	16.69
121	50/m	53.28	53.72	34.03	23.87	17.31	44.89	3.1	130	16.7
122	36/f	47.43	33.39	21.06	15.74	11.64	42.46	2.86	123	16.86
123	26/m	50.87	40.58	25.51	16.52	14.49	34.56	2.8	135	16.79
124	43/f	41.77	35.07	21.44	14.21	10.64	37.1	3.29	122	17.05
125	48/f	45.46	46.49	30.63	22.39	13.56	45.83	3.42	121	16.46
126	40/F	42.92	41.22	26.25	18.51	13.76	35.07	2.99	130	16.69

S.NO	AGE / SEX	FEMORAL HEAD DIAMETER	MEDULLARY CANAL WIDTH				HORIZONTAL OFFSET	CANAL FLARE INDEX	NECK SHAFT ANGLE	MAGNIFICATION
			D	E	F	G				
127	39/m	48.18	48.96	31.05	23.29	14.33	43.58	3.41	127	17.31
128	40/m	53.1	43.52	28.62	20.27	16.1	43.59	2.7	128	16.69
129	63/m	48.39	45.41	29.21	19.08	13.74	48.49	3.3	118	17.85
130	**<u>60/f</u>**	46.61	37.84	26.97	20.47	17.32	46.78	2.18	121	18.47
131	52/f	45.68	40.25	25.51	18.7	10.21	44.35	3.9	114	16.89
132	38/f	55.34	53.42	35.25	23.51	14.7	48.78	3.63	127	16.42
133	75/m	55.05	50.65	35.76	29.8	22.65	46.61	2.23	129	16.09
134	40/f	46.61	37.84	26.96	20.47	17.32	46.78	2.18	121	16.86
135	40/f	35.12	35.16	26.08	18.15	11.92	43.94	2.94	120	16.66
136	48/m	53.12	51.63	32.08	23.77	12.46	40.99	4.1	134	16.54
137	65/f	42.32	35.79	24.6	17.33	11.2	38.13	3.19	123	16.22
138	55/f	46.33	40.57	28.57	21.15	15.43	45.74	2.62	124	16.58
139	60/f	41.51	44.1	28.1	20.26	14.9	40.8	2.95	128	16.68
140	61/f	48.04	44.56	30.35	23.22	20.86	46.35	2.13	124	16.05
141	68/m	55.34	53.42	35.25	23.51	14.7	48.78	3.63	127	16.42
142	55/f	47.83	44.03	29.73	28.02	23.44	49.33	1.87	117	17.15
143	75/f	48.04	44.56	30.35	23.22	20.86	46.35	2.13	120	17.18
144	55/f	48.27	45.36	26.73	18.06	10.54	50.91	4.3	120	16.32
145	62/f	42.83	43.56	30.11	20.98	12.91	45.82	3.37	121	16.67
146	60/f	51.34	45.42	33.09	25.07	13.25	47.83	3.42	115	16.75
147	39/f	47.58	43.58	29.99	18.22	12.35	45.38	3.52	120	16.84
148	59/f	48.19	43.31	29.45	21.94	15.01	46.79	2.88	117	17.32
149	46/f	42.66	38.28	21.21	14.72	11.19	42.4	3.42	118	17.67
150	42/m	50.05	46.36	30.5	22.32	15.27	46.05	3.03	130	16.99
151	61/m	53.08	42.8	23.14	17.38	15.65	44.87	2.73	123	16.27
152	57/m	46.27	46.4	27.37	20.22	14.26	42.94	3.25	127	17.23
153	44/f	49.86	49.76	30.08	26.06	18.96	46.24	2.62	125	16.6
154	54/f	44.14	39.31	23.83	17.27	10.72	36.95	3.66	123	16.72
155	43/f	43.47	42.26	28.16	19.36	12.92	41.69	3.35	129	16.44
156	50/m	51.31	45.24	24.09	18.21	11.61	37.77	3.89	134	16.46
157	52/f	43.37	44.02	27	21.31	14.1	43.4	3.12	130	17.02
158	46/m	53.13	37.02	23.14	15.62	11.57	42.23	3.19	131	17.36

S.NO	AGE / SEX	FEMORAL HEAD DIAMETER	MEDULLARY CANAL WIDTH				HORIZONTAL OFFSET	CANAL FLARE INDEX	NECK SHAFT ANGLE	MAGNIFICATION
			D	E	F	G				
159	49/m	49.76	46.63	26.29	19.62	13.51	47.67	3.45	122	17.4
160	35/f	40.27	39.62	25.32	18.86	10.01	40.38	3.95	133	16.39
161	45/f	44.69	42.27	27.17	19.19	13.84	42.59	3.05	124	16.7
162	49/m	57.11	50.09	32.11	21.79	15.79	44.15	3.17	127	16.86
163	57/m	55.05	50.65	35.76	29.8	22.65	46.61	2.23	129	16.09
164	25/m	53.76	61.21	42.73	30.61	18.48	38.8	3.31	130	16.69
165	44/f	44.87	40.82	22.48	17.61	11.83	39.67	3.45	123	16.56
166	41/f	44.56	44.44	30.92	20.42	15.12	43.15	2.93	128	16.82
167	53/f	44.65	44.24	26.43	20.11	12.65	35.63	3.49	127	16.67
168	45/f	46.64	45.68	23.1	17.73	11.28	41.58	4.04	123	16.74
169	39/f	46.43	47.97	29.42	19.15	13.76	44.42	3.48	118	16.69
170	45/m	55.87	38.32	24.28	17.81	15.1	44.26	2.53	135	17.26
171	64/f	46.64	43.58	29.63	21.5	13.96	37.8	3.12	129	16.27
172	43/f	41.85	39.69	25.2	16.85	12.64	42.81	3.14	129	16.69
173	30/f	42.39	35.95	17.09	11.79	8.84	43.03	4.06	121	16.5
174	69/m	48.46	47.89	30.37	22.19	15.18	48.02	3.15	120	16.95
175	37/m	46.62	44.03	23.76	15.45	12.45	41.89	3.53	133	17.18
176	43/m	52.1	44.24	26.54	20.46	13.28	40.94	3.33	124	16.03
177	54/m	56.63	43.83	27.64	21.07	13.82	52.25	3.17	121	16.69
178	45/m	49.79	39.42	21.76	13.53	10.6	46.57	3.71	124	16.47